

Soil Solarization, an alternative to soil fumigants

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Crop Series | Soils

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What is soil solarization

Soil solarization, a hydrothermal process, occurs in moist soil when covered by plastic film and heated by exposure to sunlight during the warm months. The process changes physical, chemical, and biological properties and thereby improves soil health. It can be an alternative to soil fumigants (agricultural chemicals that have significant environmental risk, a negative impact on beneficial soil microorganisms, and that are not user-friendly).

Importance

Effective control of soilborne plant pathogens (plant parasitic nematodes, fungi, some bacteria) and weed pests is a serious challenge to farmers and home gardeners. Use of soil fumigants for pest control is often undesirable due to their residual toxicity in plants and soils, unfavorable effects on humans and animals, complexity of treatments, high cost of chemicals, and increasing interest in and demand for organic agriculture. Soil solarization is a simple, safe, and effective alternative to toxic, costly soil fumigants and to the lengthy crop rotations needed to control many damaging soilborne pathogens and pests. In addition, this procedure may provide good weed control, improve soil tilth, and increase availability of essential plant nutrients. In Colorado, effective management strategies are lacking for common soilborne problems such as replant problems, *Phytophthora* and nematode diseases in fruit crops, damping off and wilt diseases in vegetables, and bacterial and fungal diseases in commercial crops like onion. Soil solarization may be a useful tool

for producers, especially organic growers, to treat infested soil and help control weeds because of the prevalent higher summer temperatures and more than 300 sunny days in a year within the region.

Effect on soilborne pathogens

Efficacy of soil solarization for control of soilborne pathogens and pests is a function of time and temperature relationships; for example, 2-4 weeks of exposure at 99°F (37°C) may be required to kill 90% of populations for most of mesophylic fungi—an organism that grows best in moderate temperatures, 77 and 104°F, (25 and 40°C)—whereas only 1-6 hours exposure at 117°F (47°C) may be required to get the same result. During soil solarization, temperatures commonly reach up to 95°F to 140°F (35-60°C) depending on soil type, season, location, soil depth and other factors. These high temperatures induce changes in soil volatile compounds that are toxic to organisms already weakened by high temperature. Soil solarization is effective against fungal pathogens such as *Verticillium* spp. (wilt), *Fusarium* spp. (several diseases), and *Phytophthora cinnamomi* (*Phytophthora* root rot), and bacterial pathogens such as *Streptomyces scabies* (potato scab),



A weed mulcher is being used to lay plastic mulch for soil solarization.



Quick Facts

- Soil solarization at 99°F for 2-4 weeks almost completely prevents the emergence of many annual weeds.
- Efficacy of soil solarization for control of soilborne pathogens and pests is a function of time and temperature relationships.
- Solarization initially may reduce populations of beneficial microorganisms, but their populations quickly recolonize solarized soil.
- The addition of different types of organic matter to the soil before soil solarization increases efficacy of soilborne pathogen and weed management control by soil solarization.

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Agrobacterium tumefaciens (crown gall), and *Clavibacter michiganensis* (tomato canker). It also reduces soil populations of different plant parasitic nematodes, especially *Meloidogyne* spp. (root-knot) and *Pratylenchus thornei* (root lesion), *Pratylenchus* (root lesion) and *Xiphinema* (dagger) nematodes which are the most important ones for Colorado crop growers.

Effect on weeds

Soil solarization at 99°F (37°C) for 2-4 weeks almost completely prevents the emergence of many annual weeds, especially at the top layer because temperature increases more slowly at deeper depths. Soil solarization effectively controls broomrapes (*Orobanche* spp.) and many other weeds, but not *Cuscuta* species, bindweed, or purple nutsedge. Efficacy of soil solarization for weed control in the field is increased by providing irrigation at least 2-3 week prior to solarization, letting the weeds grow, and incorporating them in soil before establishing the solarization treatment.

Effect on beneficial microbes

Mild temperature increases during soil solarization are more selective towards thermophilic and thermotolerant (above 113°F or 45°C) biota, including actinomycetes. These may survive and even flourish under soil solarization, but poor soil competitors, such as many pathogens, are killed by soil solarization. Solarization initially may reduce populations of beneficial microorganisms (beneficial, growth-promoting and pathogen-antagonistic bacteria and fungi), but their populations quickly recolonize solarized soil. Plant-pathogenic fungi weakened by high soil temperatures are more susceptible to the antagonists. Nitrogen-fixing *Rhizobium* bacteria are also sensitive to high soil temperatures, and reduction in root nodulation of legumes such as peas or beans in solarized soils is also temporary. Applying inoculum to legumes planted in solarized soil may be beneficial.



Soil solarization done at Western Colorado Research Center - Orchard Mesa site. Note the clear plastic mulch, a drip irrigation hose in the center underneath the plastic, the well sealed mulch edges and fogging from water vapor on the underside of the plastic which indicates a good soil solarization.

Effect on plant nutrients

In addition, the increased availability of plant nutrients and the relative increase in rhizosphere populations of favorable bacteria, such as *Bacillus* spp. (which contribute to the marked increase in the growth, development, and yield of plants grown in solarized soil) are other major components of soil solarization benefits. Soil solarization increases nitrogen, calcium, and magnesium availability, in addition to extractable P and K. The increased availability of mineral nutrients following soil solarization includes those tied up in the organic soil fraction (e.g., NH₄-N, NO₃-N, P, Ca, and Mg). An increase in soil nitrate nitrogen by more than 3000 kg/ha was obtained in our study by adding chicken manure and growing mustard and incorporation in soil before soil solarization. Ultimately, these nutrients, especially the nitrogen, will benefit crop growth.

Addition of soil amendments

Addition of different types of organic matter, e.g., animal manures and crop residues, to the soil before soil solarization increases efficacy of soil-borne pathogen and weed management control by soil solarization. Organic matter addition increases the rate of decomposition of these materials in the soil and thereby the rate of heat generation during decomposition; it also increases the heat-carrying capacity of the soil. Volatile biotoxic compounds are released when organic matter is heated

during the process of solarization. Thus, organic amendments augment the biocidal activity of the soil solarization. In addition, organic and inorganic ammonia-based fertilizers applied to the soil and followed by soil solarization may be effective against natural soil populations of the damping off fungus (*Pythium ultimum*), *Verticillium dahliae* (in some cases), and root-knot nematode (*Meloidogyne incognita*).

Organic soil amendments can protect soil microbial biomass and enzymatic activities from the detrimental effect of heating. Different plant residues or manure incorporated into solarized soil may generate measurable amounts of volatiles such as ammonia, methanethiol, dimethyl sulfide, allylisothiocyanate, phenylisothiocyanate and aldehyde. Many plants such as several *Brassica* species produce such chemicals, including isothiocyanates in their tissues in various levels and forms including sulfur-containing compounds. Soil amendments with plant and animal byproducts increased temperature in soils beneath the plastic mulch by as much as 9.3°C (to 37.3°C or 99.1°F) even in September-October in Delta County. The temperature beneath plastic mulch in green mustard amended soil reached 129.3°F (54°C) as compared to 106.7°F (41.5°C) beneath the plastic mulch without mustard, and 78.8°F (26 °C) in non-mulched, bare soil in Western Colorado during the 3rd week of July 2010.

Soil preparation

Soil preparation should focus on creating a fine textured matrix with only small soil particles and pores, to allow moist air to penetrate the soil particles and reach the place where soilborne pathogens are located. The soil to be solarized must be loose and friable with no large clods or other debris on the soil surface. A rotary hoe or rototiller will eliminate clods or other debris that create air pockets that slow soil heating and keep the tarp from fitting tightly over the soil surface. A clean, flat surface will also prevent the accidental puncturing of the thin plastic mulch by debris.

Soil moisture

The thermal decline of soil-borne organisms during solarization depends on soil moisture and on soil temperature and exposure time, which are inversely related. Soil moisture is a critical variable in soil solarization because it makes organisms more sensitive to heat and also transfers heat to living organisms (including weed seeds) in soil. The success of soil solarization depends on moisture for maximum heat transfer; maximization of heat in soil increases with increasing soil moisture. Soil moisture favors cellular activities and growth of soil-borne microorganisms and weed seeds, thereby making them more vulnerable to the lethal effects of high soil temperatures associated with soil solarization. The interaction between temperature and soil moisture brings about cycling of water in soil during soil solarization. As the soil solarization effect penetrates deeper in the soil, the movement of moisture becomes more pronounced, changing the distribution of salts and improving the tilth of the soil and a reduction in soil salinity. A drip irrigation line under the tarp / plastic mulch to maintain moisture levels, flood-irrigation in the adjacent furrows, or pre-tarping irrigation may be enough to keep good moisture inside the soil throughout the treatment period.

Plastic tarp

Use a clear, UV-stabilized plastic (polyethylene or polyvinyl chloride) tarp or sheeting 0.5 to 3 mils thick, flexible enough to stretch across the soil surface. Two thin layers of plastic sheets separated by a thin insulating layer (3-5 cm) increases soil temperatures and the overall effectiveness of a solarization treatment. The edges of the sheets must be buried 13 to 15 cm (5 to 6 inches) deep in the soil to prevent wind from blowing or tearing the tarp. Thinner sheets (0.5 to 1 mil) are less costly, but they tear or puncture more easily. Damage to thinner plastic by birds and self shattering from UV light was severe at the Western Colorado Research Center-Orchard Mesa site, and caused failure of several soil solarization experiments. We found 1.5 mm plastic better than 1 mm

References

- Pokharel R and R. Hammon. 2010. *Increased efficacy of biofumigation by soil solarization and integrating with Brassica meal cake and poultry manure to manage soil-borne problem in onion*. Report Submitted to EPA, PESP program. Pp 23.
- Pokharel, R. R. and H. J. Larsen. 2008. *Effect of season and soil solarization on nematode population in western Colorado peach orchards*. Western Colorado Research Center, Colorado State University. Annual report, TR 010-10: 40-48.
- Pokharel, R. R. and H.J. Larsen. 2007. *The importance and management of phytoparasitic nematodes in Western Colorado fruit orchards*. Journal of Nematology 39(1): 96.
- Stapleton, J.J. 2000. *Soil solarization in various agricultural production systems*. Crop Protection 19: 837-841.
- Stapleton, J.J., R.H. Molinar, K. Lynn-Patterson, S.K. McFeeter, and A. Shrestha. 2005. *Methyl bromide alternatives... Soil solarization provides weed control for limited-resource and organic growers in warmer climates*. California Agriculture 59(2): 84-89.
- Stapleton, J.J., J.E. DeVay, and B. Lear. 1991. *Simulated and effect of ammonia-based fertilizers and soil solarization on pathogen survival, soil fertility and crop growth*. Pp. 331-342. In Soil Solarization (DeVay, J.E., Stapleton, J.J., and Elmore, C.L., eds.), Proceedings of the 1st International Conference Soil Solarization, Aman, Jordan.

plastic as it had less damage from birds and self shattering. Thicker plastic sheets (2 or more mils) should be used where damage is likely from high winds or similar problems. Holes or tears must be patched with duct tape immediately to prevent heat loss. For effective solarization, the tarp edges should be made airtight by putting soil on the edge of tarp and pressing by foot. For commercial growers, mulch layers are available and are commonly used in strawberry production in California. Be careful not to mix soils from non-solarized area into solarized area because of potential contamination of the solarized soil with pathogens and viable weed seeds.

Timing

The longer the soil is heated, the better and deeper the control of all soil pests and weeds will be. Thus, long, hot, sunny days work best to kill soilborne pathogens and weed seed. During Western Colorado's hot summers, a tarping period of 4 to 6 weeks should be enough to control soilborne plant pathogens including nematodes and weeds. However, for effective spring or fall soil solarization, a 6- to 8-week tarping period may be needed to ensure good pest control. We were able to raise the soil temperature as much as 28°C (82.4°F) by soil solarization during June-July inside the plastic mulch at Western Colorado Research Center-Orchard Mesa site during

2008. In Delta in September-October of 2009, the temperature by soil solarization reached a maximum of 82.4°F (28°C) at 6" soil depth. Soil solarization can reduce levels of infested soil if done properly. This might be a potential management option for many soilborne pathogens and pests including many weed species, especially when combined with plant and animal byproducts. Its efficacy will greatly be increased by amending the soil with green plant materials such as *Brassica* species and or animal manures, especially chicken manure, and solarizing during hot summer months. If combined with other methods, it can be used in cooler areas or seasons. Although it may not be an absolute solution, it might provide a better option for organic producers, small land holders and homeowners.