Solarization for Vegetable Weed Control

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How does soil solarization work?

Solarization is a non-chemical, hydrothermal method of soil disinfestation accomplished by passive solar heating of plastic film-covered soil. For best results, soil is moist during the heating process. The three main modes of action of solarization are physical, chemical, and biological processes. Physical inactivation of soil pests is usually the primary mechanism of action. As the soil is heated, pest organisms are damaged or killed by direct heating. However, in addition to the physical activity of solarization, chemical methods are also involved. As moist soil is heated, the organic fraction begins to break down and soluble compounds are released into the soil solution. Some of these organic compounds are biotoxic, and may cause further damage to surviving pest organisms and add to the pest control effect of direct heating. Furthermore, biological activity plays a part in the mode of action of solarization. Many of the pest organisms which are targeted by soil disinfestation (fungi, bacteria, and nematodes more so than weed propagules) tend to be somewhat physiologically specialized with regard to their preferences and tolerances for conditions in the open soil. They are more adapted for conditions present within, or in close proximity to roots of their plant hosts, rather than for competition in open soil. On the other hand, numerous other soil organisms are highly adapted to the competition of the soil environment. As the pest organisms become weakened by the effects of the physical and chemical modes of action, they are susceptible to opportunistic predation and parasitism by surviving organisms in the soil. The solarization process relies upon these mechanisms of activity, alone and in combination, to provide control of a broad spectrum of soil pest organisms.

Why use solarization?

As with any pest management approach, solarization has both benefits and limitations. Solarization can be successfully used in a variety of agricultural and horticultural situations. The primary benefits of solarization are that it is a non-chemical method of disinfesting soil, and that it costs less than many chemical treatments. Therefore, it can be used in situations where chemical soil disinfestation is not desired, not permitted, or not economically feasible. As with chemical fumigation, solarization often provides an "increased plant growth response" in subsequently planted crops. Solarization is very useful for vegetable growers in hot climatic areas, such as in the desert southwest of the U.S.A., and also in conjunction with organic farming and home gardening. It can offer broad spectrum pest control similar to the effects of chemical soil disinfestation without the risks and costs involved with chemical use. However, in cool climatic areas and during cool weather even in warmer climates, solarization may not be of significant value. Under such conditions, solarization may be combined with soil pesticides or organic amendments for increased efficacy. When practiced correctly by organic growers in warm climatic areas, solarization can be the difference between farming profit or loss, since it reduces or eliminates the need for hand-weeding. Solarization costs only a fraction of a tarped, chemical soil fumigant application, or in the case of organic farming, of hand weeding labor. Current costs range from ca. $250 (user-applied row treatment) to $800+ per acre (broadcast, glued panel treatment by custom applicator), depending on the current cost of plastic (which is based on the price of oil). In addition to organic production and gardening procedures where chemical products are not desired, solarization can be especially useful in farm production at the urban-ag interface where chemical applications are highly regulated or prohibited.

How can solarization be used?

Solarization can be applied to open fields in the same ways that tarped chemical applications are made. Most users apply solarization as a row or bed treatment, in which individual beds are covered with the clear plastic film, irrigated by drip, and solarized, while the furrows between the beds remain untreated. As in chemical soil disinfestation, this method is cheaper but does not control pests in the untreated furrow areas. On the other hand, solarization can also be applied as a broadcast treatment in which the entire field is covered with film, with the field either pre-irrigated or water run under the plastic. This is most often done by a custom applicator, since gluing of the individual plastic sheets together is the best way to accomplish the broadcast treatment.

Another specialized method of solarization is the use of a double-tent technique in conjunction with container nursery production. The California Department of Food and Agriculture has approved such a double-tent method as an alternative to soil fumigation for eradication of phytoparasitic nematodes from container nursery stock destined for field planting. The method also works well for eradicating weed propagules. The double-tent method is done by applying a layer of clear plastic film over containers of soil or planting media. This layer of film is covered by a second layer, supported by hoops or frames, to provide a still-air chamber between them. The soil in the containers is raised off the ground during treatment by placing the containers on pallets or frames to provide a layer of heated air beneath, as well as above, the containers. By using the double-tent method, temperatures in treated soil become significantly higher than those achieved during field solarization. These temperatures can rise to greater than 170 ^{0}F, which is essentially the same as achieved during soil disinfestation using aerated steam.

What are the limitations of solarization?

Since solarization is achieved via passive solar heating, there are a number of limitations that accompany its use. The primary limitation is that, for optimal benefit, the treatment must be done during the hottest part of the year. This requires that land be out of production for 2-6 weeks during the summer production season. In the deserts of the southwestern U.S.A., this is not a problem, as most vegetable ground is fallowed during the peak summer months. However, plastic film must be well-anchored to prevent wind damage in many desert areas. In other regions, growers who have adopted solarization successfully often time the soil treatment for the mid-summer period between the harvest of a spring crop and the planting of a fall crop. This works very well, but a strict schedule of cultural operations must be adhered to for best results. Since solarization provides "top-down" heating, lethal temperatures drop off deeper in the soil, and treatment during sub-optimal weather conditions or periods may not provide satisfactory results. For example, clear plastic applied to soil that does not reach temperatures sufficient to inactivate weed propagules may act as a "greenhouse" to allow luxurient weed growth. Another limitation is the existence of heat resistant weed seeds and other pest organisms. Some organisms are able to survive at quite high temperatures, and are more difficult to control by solarization. The same weed species which are resistant to the effects of solarization [e.g. the nutsedges (*Cyperus* spp.)] tend also to be difficult to control by herbicides or other soil chemical treatments. For this type of heat-resistant organism (or for use during suboptimal weather conditions), combination of solarization with other control methods, such as low dosages of chemical disinfestation products, herbicides, or biofumigants often gives improved control. Finally, solarization is primarily a knowledge-based, rather than product-based, method of soil disinfestation. Unlike chemical treatments, there are a limited number of trained consultants available to help users with technology. Most of the successful users of solarization have developed their own methodologies by trial and error, or have relied upon plastic film distributors or other growers who have mastered the technique. For that reason, we recommend that potential users of solarization start off by testing the treatment on a relatively small scale to develop their knowledge base. Since solarization is safe and relatively inexpensive to conduct, developing technical knowledge is not difficult, risky, or costly.

What new information is being developed?

Improved plastic formulations are constantly being developed. Most distributors of agricultural plastics offer products that are specifically designed for solarization. Some of the newer plastics have shown improved heating properties which may be especially useful in marginal or cooler areas. On the other hand, in very warm climates such as the Central and Desert Valleys of California, the increases in heating characteristics provided by these new generation materials usually have not resulted in significantly improved pest control. Another aid to growers which is under development is predictive maps for growers. New geographical information systems (GIS) technology has been employed to pinpoint locations of individual fields and provide historical air temperature data for these areas. Growers can access maps of their fields and get some determination of what kind of temperatures they might expect. A preliminary overview is available on the UC Kearney Agricultural Center website (http://www.solar.uckac.edu). The use of temperature maps can be coupled with information on the time-temperature dosages needed to kill specific pest organisms. A description of lethal dosages for six weed species important in California [annual sowthistle (*Sonchus oleraceus*), barnyardgrass (*Echinochloa crus-galli*), black nightshade (*Solanum nigrum*), common purslane (*Portulaca oleracea*), London rocket (*Sisymbrium irio*), and tumble pigweed (*Amaranthus alba*)] also is available on the abovementioned website.

Additional Information and References

For more information on solarization in California, including how to locate the listed references, contact your local UCCE farm advisor. These publications may provide useful information on the topics covered above:

Stapleton, J.J., 2007. Soil Solarization Informational Website. http://solar.uckac.edu/ **(This website provides comprehensive information and references on soil solarization)**

Stapleton, J.J., Molinar, R.H., Lynn-Patterson, K., McFeeters, S.K., and Shrestha, A. 2005. Soil solarization provides weed control for limited-resource and organic growers in warmer climates. California Agriculture 59:84-89. http://californiaagriculture.ucop.edu/0502AMJ/pdfs/Solarization.pdf **(This article reviews weed control via solarization for specialty crop production)**

California Department of Food and Agriculture. 2002. Approved treatment and handling procedures to ensure against nematode pest infestation of nursery stock. Nursery Inspection Proedures Manual, NIPM Item 7. Plant Health and Pest Prevention Services, Pest Exclusion Branch, Sacramento. http://www.cdfa.ca.gov/phpps/pe/nipm.htm. **(This website has a diagram of the double-tent solarization method and treatment specifications)**

Elmore, C.L., Stapleton, J.J., Bell, C.E., and DeVay, J.E. 1997. Soil solarization: A nonpesticidal method for controlling diseases, nematodes, and weeds. University of California, Division of Agriculture & Natural Resources Publication 21377, Oakland, CA. http://vric.ucdavis.edu/veginfo/topics/soils/soilsolarization.pdf **(This leaflet provides a "how-to" overview of solarization, including photographs, and includes lists of susceptible and resistant pest organisms)**

Mallek, S.B., Stapleton, J.J., and Prather, T.S. 2003. *Allium* spp., soil temperature, and exposure time affect seed viability for weed management in California. In: 2003 Proceedings of the California Weed Science Society 55:42-46. **(This article discusses the concept of**

biofumigation in relation to soil heating)

Stapleton, J.J., Prather, T.S., Mallek, S.B., Ruiz, T.S., and Elmore, C.L. 2002. High temperature solarization for production of weed-free container soils and potting mixes. HortTechnology 12(4):697-700. **(This paper gives an in-depth discussion of the double-tent solarization method for eradicating weed propagules)**

Stapleton, J.J. 2000. Soil solarization in various agricultural production systems. Crop Protection 19:837-841. **(This paper gives a more technical discussion of solarization and lists numerous other references)**

Stapleton, J.J., Prather, T.S., Dahlquist, R.M., and Elmore, C.L. 2000. Implementation and validation of a thermal death database to predict efficacy of soil solarization for weed management in California. UC Plant Protection Quarterly 10(3):8-10. <http://www.uckac.edu/ppq/PDF/00July.pdf>. **(This article discusses the development of time-temperature heat dosages needed to inactivate six weed species important in California)**