



Soil Solarization for Gardens and Landscapes

Integrated Pest Management for Home Gardeners and Landscape Professionals

Soil solarization is a nonchemical method for controlling soilborne pests using high temperatures produced by capturing radiant energy from the sun (Figure 1).

The method involves heating the soil by covering it with clear plastic for four to six weeks during a hot period of the year and when the soil will receive the most direct sunlight. Plastic tarps allow the sun's radiant energy to be trapped in soil, heating the top 12 to 18 inches to temperatures lethal to a wide range of soilborne pests; including weeds (Figure 2), plant pathogens, nematodes, and insects. When properly done, the top layers of soil will heat up to as high as 140°F, depending on the geographic location. Soil moisture is important in this process, as wet soil conducts heat better than dry soil. Moisture also makes soil pests, weakened by the heat, more vulnerable to attack by beneficial soil microorganisms during and after treatment.



Figure 1. Solarizing planting beds in a garden.

Solarization leaves no chemical residues and is a simple method appropriate for the home gardener and small- or large-scale farmers (Figure 3). Solarization is primarily used as a broad-spectrum pest control technique, but it may also improve soil health by increasing the availability of nitrogen and other nutrients to growing plants and by beneficially altering the soil microbiome.

The effect of solarization is greatest at the surface of the soil and decreases at deeper soil depths. The maximum temperature of soil solarized in the field is usually from 108° to 140°F at a depth of 2 inches and



Figure 2. Weed seedlings susceptible to solarization. From top left: black nightshade, *Solanum nigrum*; barnyard grass, *Echinochloa crus-galli*; annual sowthistle, *Sonchus oleraceus*; and common purslane, *Portulaca oleracea*.

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from 90° to 99°F at 18 inches. Control of soil pests is usually best for organisms found in the upper 6 inches of earth.

IMPACTS

Solarization during the hot summer months can increase soil temperature to levels that kill many disease-causing organisms (pathogens), nematodes, and weed seeds and seedlings.

Soil solarization also speeds up the breakdown of organic material in the soil, often resulting in the added benefit of releasing soluble nutrients such as nitrogen (from nitrate and ammonium), calcium, magnesium, potassium, and fulvic acid, making them more available to plants.

Plants often grow faster, with higher and better-quality yields, when grown following soil solarization. This may be attributed to improved disease and weed control, increased availability of nutrients, and greater proportions of beneficial microorganisms.

Effectiveness on Various Pests

The degree to which various pests can be controlled is related to the intensity, depth, and duration of the elevated soil temperatures, as well as to the sensitivity to treatment of each pest species. Although some pests may be killed within a few days, 4 to 6 weeks of exposure to full sun during the summer is required to ensure control of many others.



Figure 3. Soil solarization in an agricultural field.

Fungi and Bacteria. Solarization controls many important soilborne fungal and bacterial plant pathogens, including those that cause Verticillium wilt, Fusarium wilt, Phytophthora root rot, Southern blight, damping-off, crown gall disease, tomato canker, potato scab, and many others. A few heat-tolerant fungi and bacteria, such as those causing melon decline and charcoal rot of many crops, are more difficult to control with solarization.

Nematodes. Soil solarization can be used to reduce soil populations of many species of nematodes. This is particularly useful for organic and home gardeners. However, soil solarization is not always as effective against nematodes as it is against fungal disease and weeds. This is because nematodes are relatively mobile and can move deeper in the soil profile to escape the heat, rapidly returning to recolonize soil and plant roots following solarization treatment. Furthermore, control of nematodes by solarization will be greatest in the upper 12 inches of the soil. Nematodes living deeper in

the soil may survive solarization, later causing damage in plants with deep root systems.

Weeds. Soil solarization controls many of the annual and perennial weeds present in California. While some weed species seeds or plant parts are very sensitive to solarization, others are moderately resistant and require optimum conditions for control; that is, good soil moisture, tight-fitting plastic tarps, and high solar radiation.

Solarization generally does not control perennial weeds as well as annual weeds because perennials often have deeply buried underground vegetative structures such as roots, corms, tubers, and rhizomes that may resprout. Rhizomes of bermudagrass and johnsongrass may be controlled by solarization if they are close to the soil surface.

Control of purple and yellow nutsedge, as well as field bindweed arising from rhizomes and some clovers, can be inconsistent, even under favorable conditions. For more information about common weeds and their

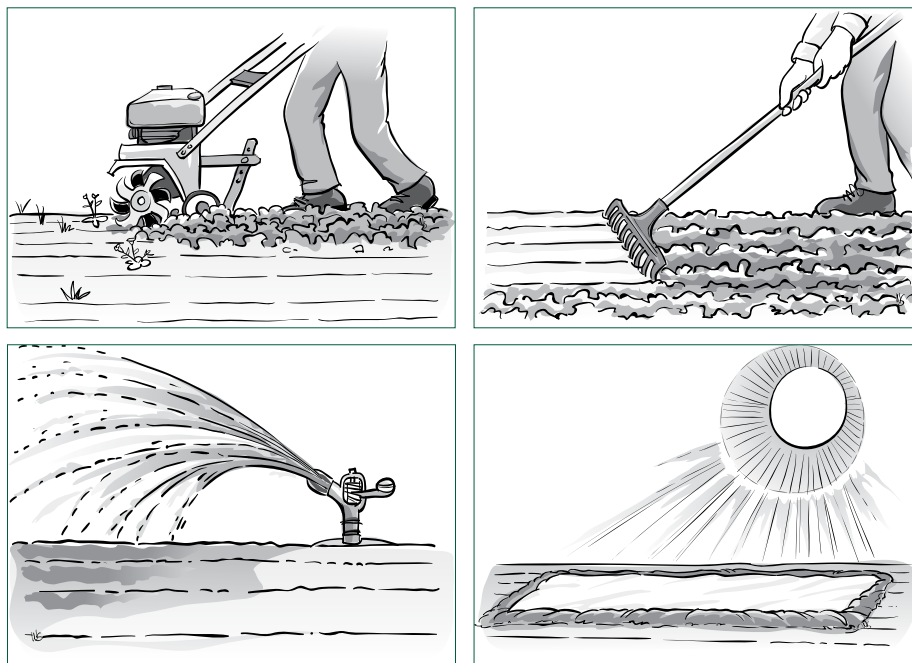


Figure 4. Follow these four steps to solarize your soil: cultivate and remove plant matter; level and smooth the soil; irrigate; and lay a clear tarp on the soil surface for 4 to 8 weeks, depending on local conditions.

management, see the *Pest Notes: Weed Management in Landscapes*.

Beneficial Soil Organisms

Although many soil pests are killed by solarization, many beneficial soil organisms are able to either survive solarization or recolonize the soil very quickly afterwards.

Important among these beneficials are mycorrhizal fungi, and fungi and bacteria that parasitize plant pathogens and aid plant growth. The increased populations of these beneficials can make solarized soils more resistant to pathogens than nonsolarized soil.

Although detailed information is lacking, earthworms are generally thought to burrow deeper into soil to escape the heat.

See *Soil Solarization: A Nonpesticidal Method for Controlling, Diseases, Nematodes, and Weeds* in References for more information about solarization and the specific pests controlled.

Biosolarization

For more experienced solarization practitioners, research and field practice has shown that it may be possible to increase the pesticidal effects of solarization treatments by incorporating organic materials, such as crop residues and composts, into the soil prior to solarization. This experimental treatment is often termed “biosolarization.”

During the decomposition of organic materials, chemical changes occur, releasing certain natural products, such as organic acids, that are toxic to organisms residing in the soil. However, caution should be exercised to not incorporate excessive amounts of organic materials during biosolarization, as treated soil may be temporarily “soured” for an extended period of time by these natural toxins. In such cases, planting must be delayed until soil conditions are suitable. Alternately, treated soil may be detoxified via irrigation, leaching organic acids and other toxins below the root zone. Research to

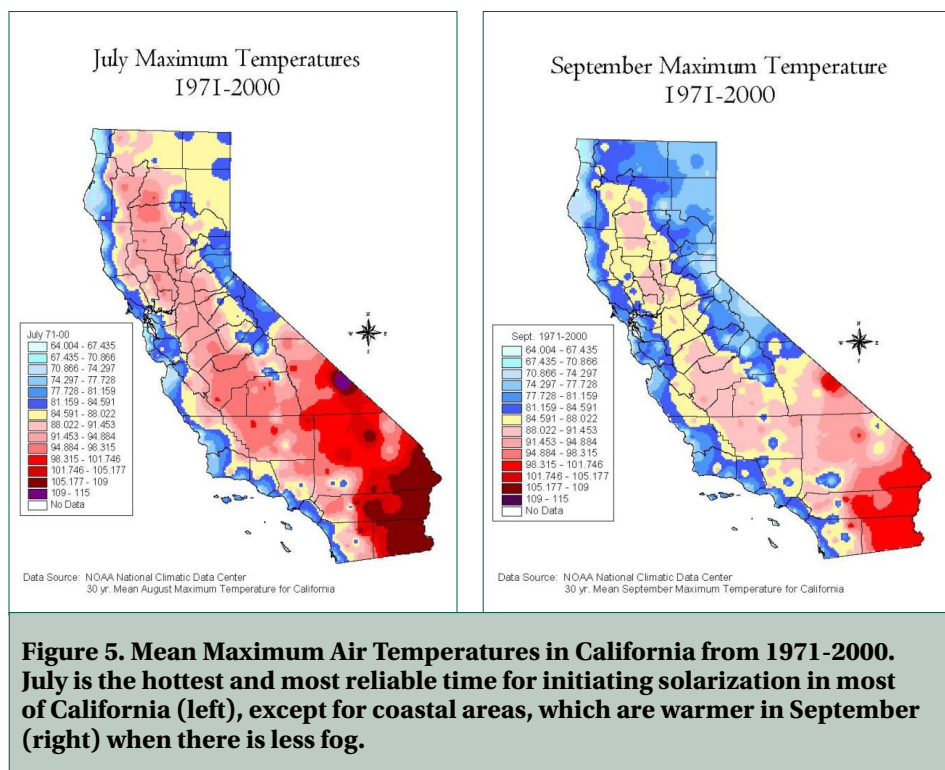


Figure 5. Mean Maximum Air Temperatures in California from 1971-2000. July is the hottest and most reliable time for initiating solarization in most of California (left), except for coastal areas, which are warmer in September (right) when there is less fog.

determine effective materials and protocols for biosolarization is ongoing.

METHOD

Where

Soil solarization (Figure 4) is most effective in warm, sunny locations such as the Central Valley, desert valleys, and other inland areas of California. It has also been used successfully in the cooler coastal areas of California during periods of high temperature and no fog. Soil treatment by anaerobic soil disinfestation (ASD) may be done where soil heating is insufficient for solarization.

When

Highest soil temperatures occur when days are long, air temperatures are high, skies are clear, and wind is minimal. The soil heating effect is not as great on cloudy days. Wind will disperse the trapped heat and may loosen or damage the plastic sheets. Shady areas may not be effectively treated by solarization.

Solarization is most effective when done during the hottest weeks of the year (Figure 5). The best time for solarization of soil in inland California is from June to August, although good results may be obtained starting as early as late May or as late as early September in the southern California desert regions. July is the most reliable time to solarize, except for coastal areas, where persistent, warm, fog-free periods may not occur until August or September. Soil within most regions of California, except high elevation areas and some coastal valleys, can be reliably solarized if treatment is instituted during the period of late June through August.

How

1. Soil Preparation

A very smooth bed, with few clods and surface litter, will allow the plastic to lie snugly against the soil, producing fewer air pockets. Air pockets between the plastic and the soil can greatly reduce soil heating and promote “sailing” of the plastic in the wind.

Solarization can be done on flat areas or raised beds. Flat areas are easiest to solarize (prior to lawn reseeding, for example) and ensure more uniform solarization of the entire area. Raised beds are best formed prior to solarization so that tarps can be placed over preformed beds. This practice also minimizes disturbance of the soil after solarization, which may bring up viable weed seeds from deeper in the soil profile.

If possible, lay raised beds out going north to south rather than from east to west to improve the uniformity of heating.

The best solarization will occur on areas where there is little or no slope or where the slope has a south or southwest exposure. Solarizing areas on north-facing slopes is not as effective and may result in reduced pest control.

2. Irrigate the Soil

For best results, wet the soil to at least 12 inches deep. In larger areas, it is easiest to do this prior to laying the plastic, but in smaller areas it can be done after the plastic is applied using a garden or soaker hose or by laying drip tape under the tarp.

If wetting soil beforehand, place plastic covers over the site as soon as possible after the water has been applied to reduce evaporation. Unless the soil gets dry during the course of soil solarization, or you are aiming to do an ASD treatment, do not irrigate again, as this will lower the soil temperature and lengthen the time required for successful solarization.

3. Plastic Tarp Choice

Plastic material. In general, transparent or clear plastic is most effective for solarization, as the heating rays from the sun will pass through the sheet and be trapped to heat the soil below.

Usually black plastic is less effective because it absorbs and deflects part of the heat, rather than trapping as clear plastic does. However, in cooler or coastal areas, black plastic is sometimes better than clear, because weeds won't grow

beneath it, as they will under clear plastic when the air temperatures are too low to kill them. In this case, the black plastic should be left in place for several weeks during the hottest part of the year.

Several thicknesses of plastic tarp are available. (Note: 1 mil = 0.001 inch or 0.025 mm)

- Thin plastic provides greater heating, but is also more susceptible to tearing from wind or animals walking on it (1 mil).
- Slightly thicker plastic is better in windy areas (1.5 to 2 mils).
- Thicker plastic can be used if the treated area is small (4 mil or more).

Plastics designed for large-scale solarization are usually treated with an ultraviolet (UV) inhibitor so they will not break down as quickly in sunlight. For use in gardens, the rolls of 1 to 4 mil "painter's" plastic are available at larger hardware stores and are easier to obtain. These should last for the 4 to 6 week solarization period without beginning to break down. When available, select clear, transparent film, rather than cloudy, milky, or translucent materials which will reduce solar energy transmission.

Plastic sheets without UV protection should be watched closely, so they can be removed before deteriorating to the point where removal and disposal are difficult. If a longer solarization period is desired, small areas can be covered again with fresh plastic. Any holes or tears should be patched with durable patching tape.

For treating small areas in a garden, or on a lawn in cooler climates, it may be helpful to use a double layer of plastic with air space created by objects such as plastic bottles or PVC pipe between the layers. This has been shown to raise soil temperatures an additional 2° to 10°F over temperatures obtained with a single layer of clear plastic.

4. Plastic Tarp Placement

Flat beds. The plastic must be held as

tightly as possible against the soil. One way to hold it down is to dig a trench 4 to 6 inches deep around the area that is going to be solarized. Lay the plastic out over the area with one edge in the trench. Cover that edge with soil to hold it down. Pull the plastic tight from the other side and bury that edge in the corresponding trench. Do the same with the other sides and then walk around the perimeter of the trenched area to pack the soil down around the edges of the plastic. The closer to the soil surface the plastic is, the better the heating.

Raised (formed) beds. As with flat beds, the plastic must be held close to the soil. Multiple beds can be covered by a single sheet of plastic, but heating may be reduced and the plastic may "sail" when it is windy. If only single beds are covered, the furrows between the beds are left uncovered and are not solarized. Each bed is covered with a strip of plastic tarp that is wide enough to cover the entire bed width and have enough tarp left over to bury the edges to hold it down. Avoid moving soil from the untreated furrows to the beds because this may re-infest the treated beds with pests.

5. Solarizing Period

Solarization is both time- and temperature-dependent. The cooler the soil temperatures, the longer the plastic needs to remain in place to raise the temperature to desired levels. The goal is to maintain daily maximum temperatures in the top 6 inches of soil at or above 110° to 125°F. Use of a soil thermometer or temperature probe can verify achievement of these temperatures.

Four to six weeks of soil heating during the warmest time of the year is usually sufficient to control most soil pests. In cool, windy, or cloudy locations, or if there are pests present that are difficult to control, it may be necessary to leave plastic in place up to 8 weeks. Conversely, during very hot weather, pests may be controlled with a shorter period of solarization. For instance, most soilborne pests will be controlled

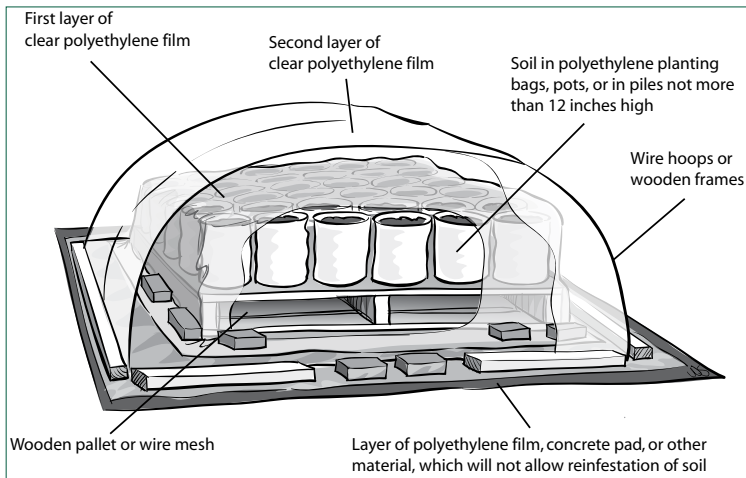


Figure 6. To solarize soil in containers, place soil in buckets or bags on an elevated surface and cover with a double tent of two layers of clear polyethylene film.



Figure 7. Nursery planting media under double-layer plastic for solarization.

after only 4 weeks of solarization during June through September in California's Central Valley and desert regions.

6. Post-solarization

Removal of Plastic. After solarization, the plastic may be removed, taking care not to disturb the underlying soil to avoid bringing up viable weed seeds from untreated edges and furrows or from deep layers that did not reach lethal temperatures. The area can be planted immediately with seeds or transplants for a fall or winter crop or a lawn.

Alternatively, the plastic may be left on the soil as a mulch by cutting holes and transplanting plants through the plastic.

Clear plastic may be painted white or silver to cool the soil and repel insect pests. However, the plastic tarp may degrade and fall apart during the growing season.

If the soil will be cultivated prior to planting, the cultivation should be shallow (less than 2 inches deep) to avoid bringing viable weed seeds and pathogens to the surface.

Solarizing Soil in Containers

Soil solarization has been shown to be effective for disinfesting small amounts of moist, containerized soil and soil in cold frames. Soil can be solarized either in bags, pots, plastic buckets, or flats. These containers are placed on an elevated surface such as wooden pallets and covered with a double tent of transparent plastic (Figures 6 and 7).

Soil temperatures should be monitored closely in this planting medium to assure that temperatures are high enough to control pests. As an example, in warmer areas of California, soil inside black plastic bags can reach more than 160°F during solarization. This is equal to target temperatures suggested for commercial soil disinfestation using

aerated steam. At these temperatures, all soil pests can be killed within 1 hour.

The double layer of plastic can increase soil temperatures by up to 50°F, and placing containers on pallets allows for heating from all sides of the soil mass.

Alternatively, moist soil in pots, or as a mass, may be placed in closed black trash bags and placed on pallets. Soil temperatures can be monitored using simple soil thermometers inserted into the center of the soil mass, or by using thermocouples and a digital reading logger.

Temperatures can be monitored at multiple locations, but the duration should be lengthened to raise the temperature at the coolest location to the desired level. As a guideline, to completely eliminate pests, maintain 158°F or higher for 30 minutes, or 140°F or higher for 1 hour.



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WARNING ON THE USE OF PESTICIDES

Pesticides are poisonous. Some pesticides are more toxic than others and present higher risks to people, nontarget organisms, and the environment. A pesticide is any material (natural, organic, or synthetic) used to control, prevent, kill, suppress, or repel pests. "Pesticide" is a broad term that includes insecticides, herbicides (weed or plant killers), fungicides, rodenticides, miticides (mite control), molluscicides (for snails and slugs), and other materials like growth regulators or antimicrobial products such as bleach and sanitary wipes that kill bacteria.

Always read and carefully follow all precautions and directions provided on the container label. The label is the law and failure to follow label instructions is an illegal use of the pesticide. Store all chemicals in the original labeled containers in a locked cabinet or shed, away from food or feeds, and out of the reach of children, unauthorized persons, and animals. Never place pesticides in food or drink containers. Consult the pesticide label to determine active ingredients, correct locations for use, signal words, and personal protective equipment you should wear to protect yourself from exposure when applying the material.

Pesticides applied in your garden and landscape can move through water or with soil away from where they were applied, resulting in contamination of creeks, lakes, rivers, and the ocean. Confine pesticides to the property being treated and never allow them to get into drains or creeks. Avoid getting pesticide onto neighboring properties (called drift), especially onto gardens containing fruits or vegetables ready to be picked.

Do not place containers with pesticide in the trash or pour pesticides down the sink, toilet, or outside drains. Either use all the pesticide according to the label until the container is empty or take unwanted pesticides to your local Household Hazardous Waste Collection site. Contact your county agricultural commissioner for additional information on safe container disposal and for the location of the Hazardous Waste Collection site nearest you. Follow label directions for disposal of empty containers. Never reuse or burn the containers or dispose of them in such a manner that they may contaminate water supplies or natural waterways.

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