Soil Solarization

Soil solarization is a nonpollutant method effective to control a variety of soil pests and diseases (Katan and DeVay, 1991).

From: Organic Farming, 2019

Related terms:

Nematode, Pests, Soil, Fields, Crops, Weeds, Plastics, Surfaces, Inoculum, Crop Rotation

Learn more about Soil Solarization

Integrated Weed Management in Organic Farming

Charles N. Merfield, in Organic Farming, 2019

5.8.1.1 Soil Solarization

Soil solarization was originally developed to control soilborne pathogens (Katan et al., 1976). It was then quickly discovered that it was effective against a wide range of soilborne pests and weeds. Solarization works by heating the soil to sufficient temperatures (at least 40–55°C) for sufficient duration (several weeks), that it kills weed seeds in the soil, and some perennial weeds with perennating organs close to the surface (Cohen and Rubin, 2007). This is achieved by ensuring the soil is maintained at field capacity, then covering with transparent polythene sheet. The soil needs to be kept moist as this improves heat conduction into the soil and also some pests and weed seeds are more susceptible to thermal treatment when moist. Transparent polythene acts in a similar fashion to a glasshouse, in that it allows the visible light from the sun to warm the soil, but then traps the infrared heat released by the soil. Black polythene does not work as well, as although the polythene itself heats up, most of that heat is lost to the atmosphere and not transferred to the soil.
The duration required is dependent on both air temperature and the amount of solar radiation, so the technique works best in hotter climates and at lower latitudes, e.g., below approximately 50°C, latitude. In many climates it will only work in summer, even mid-summer, and with treatment durations of 3–6 weeks, it ties up productive land in the middle of the cropping season. Solarization is therefore not used as a routine measure, but is mostly reserved to address weed problems that are intractable by other means. Many organic standards also limit its use due to its negative effects on soil biology.

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**Principles of soil solarization**

The principles of soil solarization are summarized as follows:

1. Solarization heats the soil through repeated daily cycles. At increasing soil depths, maximal temperatures decrease, are reached later in the day, and are maintained for longer periods (Figure 1); Figure 1. The daily course of soil heating by polyethylene at three soil depths, as compared to nonsolarized (no mulch) soil at a depth of 10 cm. Typical results obtained during July–August in Rehovot, Israel.

2. The best time for soil mulching, i.e., when climatic conditions are most favorable, can be determined experimentally by tarping the soil and measuring the temperatures. Meteorological data from previous years and predictive models further aid in this task;

3. Adequate soil moisture during solarization is crucial to increase the thermal sensitivity of the target organisms, improve heat conduction in the soil, and enable biological activity during solarization. The soil can be moistened by a single irrigation shortly before tarping. Additional irrigation during solarization via drip system or furrow irrigation is usually not necessary, except for very light soils; in addition to which it may reduce soil temperatures unless carried out during the night;

4. Proper preparation of a soil ready for planting is essential. This is the case because, after plastic removal, the soil should be disturbed as little as possible to avoid recontamination;

5. The soil is mulched with thin, transparent polyethylene sheets or other plastic material. Another method of solarization involves a closed glasshouse (or
6. Novel technologies such as the use of sprayable plastics can replace plastic mulching of the soil; successful pathogen control in various regions of the world is usually obtained within 20–60 days of solarization. Extending the solarization period enables control in deeper soil layers, as well as of pathogens that are less sensitive to heat;

7. Solarization causes chemical, physical, and biological changes in the soil that affect pest control, plant growth, and yield.

Although both solarization and artificial soil heating involve soil heating, there are important biological and technical differences between these two methods of soil disinfestation. With soil solarization, there is no need to transfer the heat from its source to the field. It can therefore be carried out directly in the open field or in the greenhouse. Solar heating is carried out at relatively mild temperatures (Figure 1), as compared to artificial heating, which is usually carried out at 70–100°C; thus, the former’s effects on living and nonliving soil components are likely to be less drastic. Indeed, negative side-effects observed with soil steaming in certain cases, e.g., phytotoxicity due to the release of manganese or other toxic products and rapid soil reinfection due to the creation of a ‘biological vacuum,’ have rarely been reported with solarization. This term refers to a situation where microbial populations are much reduced, resulting in an unbalanced population of soil microflora. Nevertheless, the possibility of the occurrence of such negative side-effects should not be excluded a priori. Under appropriate conditions, many soilborne pathogens such as fungi (e.g., Verticillium, Fusarium, Phytophthora, Pythium, Pyrenochaeta), nematodes (e.g., Pratylenchus and Ditylenchus), and bacteria (e.g., C. michiganensis), as well as a variety of weeds, especially annuals, are controlled by soil disinfestation and consequently yields are increased.

As with any soil disinfestation method, soil solarization has advantages and limitations. It is a nonchemical method with less drastic effects on the biotic and abiotic components of the soil; it is simple (and is therefore suitable for both developing and developed countries); and it is frequently less expensive than chemical soil disinfestation. The limitations of this method stem from its dependence on climate and it can therefore be used only in certain climatic regions and during limited periods of the year. In addition, during solarization, the soil remains without a crop for several weeks. Nevertheless, this method has attracted many researchers in more than 60 countries and it is used by farmers, especially in combination with other methods.

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4 Soil Solarization

In areas with extended periods of hot weather, use of plastic tarps to heat moist soil prior to planting (soil solarization) has proven useful as a means of killing weed seeds and reducing weed seedling densities in subsequent crops (Egley, 1983; Horowitz et al., 1983; Standifer et al., 1984; Elmore et al., 1993). Kumar et al. (1993) provided data indicating the positive effects of soil solarization on both weed suppression and crop yields, although the effect on crop yield might be attributed to reductions in pathogen populations as well as reduction in weed pressure (Stapleton and DeVay, 1986).

Role of Microorganisms (Mycorrhizae) in Organic Farming

Ibrahim Ortaş, in Organic Farming, 2019

6.12 Soil Solarization

Pesticides and other methods do not always control these destructive pests and soilborne diseases. Very recently alternative methods have been suggested, such as soil solarization. Soil solarization and using organic sources together, such as compost application, are very important for alternative methods of controlling damaging nematodes, soilborne fungi, and bacterial diseases. Recently soil solarization has been concentrated on, using mycorrhizal inoculation for better plant nutrition and healthy plant growth. Because of the undesirable effects of MBr on other soil organisms, new alternatives have been searched for. Soil solarization if especially useful for the Mediterranean coastal area, as there are over 250–270 sunshine days. Solarization is important as an alternative solution to agrochemical application.

The methodology is simple. After soil was plowed and irrigated, the soil surface is covered with a polyethylene sheet. Over 3 and 4 weeks the time soil temperature in the surface reaches up to 50–55°C. Under this condition, soil organisms are partially eliminated. After the sheet is removed from the soil surface, the soil is ready for seed and seedling sowing.
BACTERIA | Plant Growth-Promoting

Y. Bashan, L.E. de-Bashan, in Encyclopedia of Soils in the Environment, 2005

Biocontrol of Phytopathogens

Phytopathogenic microbes have an immense impact on agricultural productivity, greatly reducing crop yields and sometimes causing total crop loss. Usually, growers manage phytopathogens by employing chemical pesticides and, to a lesser extent, expensive steam sterilization and ‘soil solarization.’ The main drawback of the chemical management strategy is that the target plants often remain infected but non-symptomatic for prolonged periods, thus, untreated. Small environmental shifts can produce uncontrollable epidemics. Additionally, pesticides are expensive, hazardous, affecting human and animal health when they accumulate in the plants and soil, and eliminate beneficial soil and biocontrol organisms. A better strategy to avert the development of epidemics is to treat the pathogen when its levels in the field are low, to prevent further increases over the growing season. Effective options include employing the pathogen’s natural enemies as biological control agents or developing transgenic plants that are resistant to the pathogen. Both strategies are considered less destructive or more ‘environmentally friendly’ than chemical treatments. Several biocontrol-PGPB are commercially available.

Environmentally friendly desert agro-biotechnologies

Zeev Wiesman, in Desert Olive Oil Cultivation, 2009

Soil solarization

Though soil-borne pests can be controlled in fruit trees by pre-planting application of pesticides, including the fumigants methyl bromide, chloropicrin and metam sodium (Katan, 1984), the use of these chemicals is often undesirable owing to their toxicity to animals and human beings, their residual toxicity in plants and soils, their complexity, and the high cost of treatment. Furthermore, restrictions on the use of soil-applied pesticides appear to be imminent as future environmental
legislation is being implemented. To overcome this problem and remove soil-borne pests, solarization is considered the best technique (Di Primo et al., 2003).

**Soil solarization** offers a simple organic solution to the problem. Solarization can control *Verticillium*, *Rhizoctonia solani*, *Fusarium oxysporum* f. sp. *vasinfectum* or *melonis*, *Orobanche*, *Sclerotium rolfsii*, *Pratylenchus* and others, as well as weeds, and can also increase yield.

By placing transparent plastic sheets over moist soil during periods of high ambient temperature, the sun's radiant energy can be absorbed and trapped by the soil, thereby heating the topsoil layer. Solarization during the hot summer months can increase the soil temperature to high enough levels (solar energy in the Negev area is estimated to be 195–201 kcal/cm² per year) to completely eradicate pathogens, nematodes, weed seeds and seedlings. It leaves no toxic residues, improves soil structure, and increases the availability of nitrogen (N) and other essential plant nutrients.

Soil solarization is a basic technique for Negev farmers, especially for off-season vegetable and flower production for the export market. It offers a simple, cost-effective, non-pesticidal treatment. This technique is equally useful in olive production, and can also increase the productivity of olive trees in an arid environment.

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**Prospects for the Use of Chitosan and Other Alternatives in Ornamental Conservation**

Laura Leticia Barrera Necha, Silvia Bautista-Baños, in *Chitosan in the Preservation of Agricultural Commodities*, 2016

**Physical alternatives**

**Sanitation**

The extensive adoption of soilless medium has eliminated many disease problems caused by soil-borne plant pathogens in ornamentals production. Soil is still used as a potting mix component or in ground beds. The accepted treatment for freeing soil from pathogens since the 1960s has been the use of aerated steam for pasteurization [16–18], which leaves some beneficial microorganisms in the soil rather than creating a biological vacuum. Structural solarization recently has been developed for
Anand and Gautam [20] reported the use of soil solarization, fungicide gladiolus corm dip, and soil amendments for Fusarium wilt. Corms were treated with carbenzadim, carbenzadim + mancozeb (0.2%) or Trichoderma viride formulation (0.5%) before sowing. Three fungicide drenches at 10-day intervals for a month after sowing of corms were found quite effective. Soil amendments with cabbage leaf residue together with soil solarization were found to be the most effective treatment for disease control (98.5%).

Water used for irrigation can also be a source of pathogens or can provide a medium by which pathogens are introduced to plants. The technology for water disinfestation by physical, chemical, and biological means is critically important for greenhouse and nurseries using recirculating irrigation [21,22].

Therapy

A key aspect of plant health management is starting with clean propagative material. Most ornamentals are multiplied via vegetative propagation, which means a greater danger of pathogen passage than in seed propagated crops. Therapies is sometimes employed to free plant pathogens [23]. Hot water can be used for pathogen eradication from corms, bulbs, tubers, and seeds, and has the advantage of penetrating to internally harbored pathogens. Crop sanitation includes control of weeds that are pathogen reservoirs as well as control of arthropods that vector pathogens [24]. Although short-term exposure to high temperature will often free seeds from bacteria and fungi, generally longer periods of exposure are more effective for eliminating viruses [25]. Aerated steam used at 56–57°C for 30 min is safer than hot water and more effective than air for seed treatment [26]. Although short-term exposure to high temperature will often free seeds from bacteria and fungi, any heat treatment poses a risk of reduced germination percentage. As a result, this approach is not widely used by the flower seed industry.

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**BIOCONTROL OF SOIL-BORNE PLANT DISEASES**


**Introduction**

Soil-borne root diseases are one of the more intractable problems associated with achieving the sustainability of agriculture. Their occurrence is generally a sign of a bi-
ological imbalance within the soil ecosystem, where the natural enemies, predators, competitors, or antagonists of root parasites or disease-causing organisms are low in number and/or activity. This biological imbalance or loss of natural suppressiveness of the soil toward disease-causing organisms can, in many instances be associated with conventional agricultural management practices such as intensive soil cultivation, overuse of fertilizers and other agrochemicals, and continuous cropping. All of these practices tend to have a negative impact on the physical, chemical, and biological attributes of soil quality/health. In some cropping systems such as high-value vegetable and fruit crops, soil fumigation (or solarization) may be used to sanitize the soil and still permit growers to plant the same crop in the same field time after time. However, such practices, which work against the soil biota and debilitate its natural suppressive qualities, are not sustainable in the longer term.

Biological management or control of soil-borne root diseases has been a fruitful area of research for the past 40 years. There have been two basic research approaches. The first approach involves enhancement of the natural suppressiveness or biocontrol capability of microbial communities in the soil toward root disease organisms, through the use of alternative agricultural practices. These practices include the greater use of crop rotations and the use of organic amendments to stimulate soil microbial activity and provide a source of plant nutrients. The second approach involves the deliberate use of specific antagonist organisms for prevention and management of specific root diseases. These microbial biocontrol agents are usually single strains of bacteria or fungi which have been isolated from a soil and shown to have antagonistic properties toward the targeted root disease organism. They have been used in a number of ways, including direct addition to soil to reduce inoculum levels of pathogens in the soil and applied to seeds to protect against seed and root infections. The potential use of microbial biocontrol agents in agriculture has been hampered by numerous technical difficulties (inconsistent performance, formulation, and delivery) and complex and expensive regulatory protocols.

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Pest Control in Organic Farming

Cristina A. Costa, ... Anabela Nave, in Organic Farming, 2019

3.3.2.5 Physical and Cultural Control

Organic farming relies on methods which combine scientific knowledge of ecology and modern technology with traditional farming practices based on naturally occurring biological processes. The physical and cultural control methods, that aim at
eliminating or reducing the amount of the pest or pathogen present in the field or
to enhance the beneficials’ activity, include crop rotation, intercropping, cover crops,
mulches, and soil solarization to reduce pest and disease incidence. Other methods,
such as flooding, deep plowing, fire and flaming, may also be used (Katan, 2010).

**Crop rotation** is an ancient and important agricultural practice with an important role
in improving the quality of crops, soil fertility, and also, crop protection. Continuously cropping the same crop builds up the population levels of pests and pathogens that live, at least a part of their life cycle, in the soil (Yuliar et al., 2015). By defining a sequence of different crops on the same field—crop rotation—it is possible to reduce pest and pathogen populations just because they are not suited to the host plant. For example, crop rotations using Chinese chive (*Allium tuberosum*) and tomato have reduced the incidence of bacterial wilt (approximately 60%) because the root exudates of Chinese chive may prevent *R. solanacearum* from infecting tomato plants (Yu, 1999). Rotations are good for controlling host-specific pests and diseases such as potato cyst nematode and eyespot of cereals. They are not as effective against general pests such as slugs, and are unlikely to have any effect on migratory pests such as birds.

Another great benefit of rotations is the renewal of fertility and improving soil structure that is directly related to the ability of a crop plant to resist or tolerate insect pests and diseases and with soil biodiversity (Altieri et al., 2012; Tiemann et al., 2015; Venter et al., 2016). Data collected from several studies prove that longer rotations produced stronger positive effects on belowground communities. Positive ecological interactions between soils and pests should be enhanced to optimize agroecosystem function (Altieri et al., 2012).

**Intercropping** or *consociated species* refers to the special cropping system obtained by growing two or more species in the same space and time, whose association may generate reciprocal benefits. Agricultural specialists suggest intercropping has also the ability to reduce pests and diseases (Fig. 3.7A) (Shennan, 2007; Carrubba et al., 2008).

![Figure 3.7](image.png)

**Figure 3.7.** (A) Intercropping, (B) cover crops, and (C) mulching.

Intercropping contributes to crop protection by breaking pest and disease cycles, creating barriers to the spread of pests and diseases, enhancing arthropod biodiversity, namely natural enemies, by providing alternative food, shelter, and repro-
duction sites, and generating conditions for better plant health which are known to increase plant resistance. The use of consociated crops might also benefit from plant indirect defense mechanisms based on allelochemical effects: volatiles (alkaloids, monoterpenoids) produced by plants that can influence, directly or indirectly, other organisms (plants, pests, diseases) (Fürstenberg-Hägg et al., 2013). The allelochemicals produced by plants are released by washing the leaves by rainfall or irrigation, through the root exudates, and by volatilization. Some examples of plants that help to avoid pests and diseases are, for example, Artemisia absinthium L, commonly called absinthium or wormwood, that repulses mammals, acari, cabbage butterfly, several flies and fungus like Fusarium solani or Fusarium oxysporum, or Allium cepa to control mites, ants, and storehouse pests (Chiasson et al., 2001; Moore et al., 2006; Stoleru and Sellitto, 2016).

Cover crops are crops planted to manage soil erosion, soil fertility, soil quality, water, weeds, pests, diseases, biodiversity, and wildlife in an agroecosystem (Fig. 3.7B) (Lu et al., 2000). As previously referred, they also provide habitat for beneficial predator insects, supplemental food source to insects and wild bees in the form of nectar from their flowers and act as nonhost crops for nematodes and other pests in crop rotations (Nunes et al., 2015).

Another cultural practice that helps controlling pests and diseases is mulching (Fig. 3.7C): the use of a layer film of organic materials applied to the soil surface, blocking nearly all light from reaching the surface, to preserve moisture, improve the fertility and health of the soil, and reduce weed growth and infestation with different pests (Stoleru and Sellitto, 2016). In organic farming, mulches may be biodegradable (e.g., bark chips, straw, organic newspaper, killed cover crop residue left on the surface, biodegradable plastics or nets). It may be applied to bare soil or around existing plants. All mulch types suppress insects in comparison with bare soil.

Soil solarization is a nonpollutant method effective to control a variety of soil pests and diseases (Katan and DeVay, 1991). The method employs solar energy through a thin transparent film (0.03–0.05 mm) that is laid on the previously watered ground surface, during the warmest months of the year and for a period of time not less than 30 days. The soil should be prepared in order to ensure the homogeneity and perfect fragmentation of the soil, to a shallow depth, to obtain a plain and straight surface, inner condition to the application of the film in the ground (Fig. 3.8). The soil should be copiously watered (with a volume of at least 30 mm of water per square meter), using irrigation by gravity or another technique, for for a period of two days. The presence of water in the soil is essential to increase the thermal conductivity, ensuring heat penetration into the soil and solarization efficiency.
Figure 3.8. Soil solarization process: (A) soil preparation to obtain a plain and straight surface; (B) irrigation using gravity technique or other; (C) placing and stretching the transparent film; and (D) solarization for a period of 30 days during the warmest months of the year.

The high temperature levels in solarized soil reach lethal and sublethal levels to pathogens, insects, and vertebrates (Yaduraju and Mishra, 2004; Vitale et al., 2010). It may be applied in vegetable crops, in presowing or preplantation, in greenhouses or outdoors. In perennial crops it should be used during preplantation or after the plantation stage, but in this case, its utilization should not be generalized. It should be done with adequate mobilization of the ground, achieving 20 or 30 cm depth.

Solarization success depends on the amount, depth, and duration of increased soil temperature, but also on the thermal sensitivity of the target organism and the density of the agent populations in the soil (Vitale et al., 2010; Yuliar et al., 2015). Soil solarization has proved to be effective in the control of plant diseases caused by soil fungi (Fusarium oxyporum, Plasmodiophara brassicae, Pythium ultimum, Sclerotinia spp., Pyrenochaeta terrestris, P. lycopersici, Rhyzoctonia solani, and Verticillium dahlia), nematodes (Heterodera carotae and Meloidogyne spp.), bacteria (Agrobacterium tumefaciens), and arthropods that live in the soil.

Other cultural practices, such as sowing and harvest timing, cultivation, and canopy management using green interventions, might contribute to reduce pest and disease severity (Costa et al., 2016; Stoleru and Sellitto, 2016).

Careful timing of sowing and harvesting operations may avoid pests, and to some extent diseases: early sowing spring oats and winter rye allows the plants to grow enough to avoid damage by fly larvae (Oscinella frit) or late carrot sowing ensures that plants emerge between the first and second flight periods of the carrot fly (Psila rosae) (Fidler and Webley, 1960; Berry et al., 1997; Huusela-Veistola et al., 2008).
Cultivations (or tillage) may also limit pest and disease attack. A well-prepared seed bed will allow the crop to grow quickly and avoid some problems, reducing the activity of invertebrates, such as slugs and leatherjackets, which require protection from the soil. Also, good trash burial will remove sources and disrupt soil organisms’ life cycles (Stoleru and Sellitto, 2016).

Some invertebrate pests can be physically excluded from crops. For this, a barrier, such as fleece or fine plastic net, is required. This can be effective, for example, in excluding carrot fly from a crop of carrots, but it is only justified on valuable crops such as vegetables (Nunes et al., 2015).

> Read full chapter

**Integrated Pest Management**

P. Karuppuchamy, Sheela Venugopal, in *Ecofriendly Pest Management for Food Security*, 2016

**5.7 Physical Methods of Pest Control**

Physical interventions exploit a physical characteristic of the environment in order to manipulate pest populations. Different temperatures, humidity levels, and even atmosphere can be used to manage pests, as can mechanical intervention. In situations where the farmer has a large degree of control over the physical environment, such as greenhouses, physical interventions can be the most important methods of IPM. Even in field situations, physical manipulations such as compaction, flooding, or mulching can adversely affect potential pests.

1. **Temperature**: Heat can be used to manage pests. Examples include soil solarization, flaming, burning, etc.
2. **Water**: Moisture level can be manipulated to manage pests. Flooding is an example.
3. **Air**: Atmospheric manipulation can be used to manage a pest. This method is usually associated with storage of harvested product in high-nitrogen or high-carbon dioxide environments.
4. **Light**: The behavior of certain species of insects being attracted to light could be advantageously used in their management. The light traps could be used both for monitoring and as a means of control. Mohan and Janarthanan (1985) reported that the rice stem borer and the brown plant hopper responded more toward a yellow light source, while the rice leaf folder and green leaf hoppers responded to a green light source.
**Physical agents:** Physical forces minimize certain pests. A material called drie-die consists of highly porous, finely divided silica gel that when applied abrades the insect cuticle thus encouraging loss of moisture resulting in death. It is mainly used against stored product pests. Kaolinic clay after successive activation with acid and heat can be mixed with stored grain. The clay minerals absorb the lipoid layer of the insect cuticle by which the insects lose their body moisture and die due to desiccation. Artificial heating and cooling of stored products prevent insect damage. Usually high temperatures are more effective than low temperatures. Stored products can be exposed to 55 °C for 3 h to avoid stored product pests. Steam sterilization of soil kills soil insects and is done by vapor heat treatment: Heated air is saturated with water (>RH 90%) for a specified period of 6–8 h for raising pulp temperature to 43–44.5 °C for mango against fruit flies. Activated clay or vegetable oil at 1% effectively reduced the damage by pulse beetle, *Callosobruchus chinensis* (Linnaeus). Solar heat treatment of sorghum seeds for 60 s using solar drier resulted in 100% mortality of rice weevil, *Sitophilus oryzae* (L.) and red flour beetle, *Tribolium castaneum* Herbst. There was no reduction in germination percent of seeds (Mohan et al., 1987). Biogas fumigation for a period of five days resulted in complete mortality of eggs, grubs, and adults of pulse beetle (Mohan et al., 1989).