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Soil Solarization: A Sustainable Strategy of Soil Pest, Disease and Weed Management

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Abstract

Use of translucent polyethylene plastic mulch as a pre-plant method of soil disinfestation, known as "soil solarization" (SS), aims to eliminate or significantly reduce crop pests, dormant weed seeds and current weed seedlings. The aim is to create a "greenhouse effect". Weed and other plant pests are eliminated if the temperature in the soil and beneath the plastic film gets hot enough. Weeds are a significant problem in crop production. Weed scientists are now facing new challenges, especially because of the rise in herbicide resistance and residues from herbicides. The most effective method of controlling pre-emergent weeds is soil solarization; it leaves no toxic residues and is currently adopted all over the world. When plants are planted in solarized soil, they frequently grow more quickly and give higher-quality, more abundant crops.

Keywords: Plastic, Soil, Solarization, Weed

Introduction

Since the advent of the green revolution, the prevalent method for controlling soil-borne pests, diseases and weed seeds has been the use of synthetic pesticides and weedicides. However, these methods are detrimental to soil, human and crop health. As a result, modern agriculture has pivoted towards sustainable strategies that minimize the use of chemical methods for crop production. In the quest for improved crop management practices, farmers and scientists have been searching for an alternative strategy. Soil solarization is one such strategy, this method is said to be an environmentally friendly method for weed, pest and disease management. Soil solarization controls soil pathogens, nematodes, weed seeds and more by harnessing solar heat or energy. Solar radiation is captured by a polyethylene cover, which raises the soil's temperature to a point where nematodes, weed seeds and other disease-causing organisms cannot survive. Soil solarization can be adapted on both small and large scales. It operates primarily through thermal and hydrothermal mechanisms, where captured solar radiation heats the applied soil water and topsoil. Interestingly, plants grown in solarized soil often exhibit faster growth and yield higher and better-quality produce. Improvements in weed and disease control may be partially responsible for this, but pest-free solarized soil also shows increases in growth. Other names for soil solarization include mulching or tarping with plastic or polyethylene and soil pasteurization.

Principles of Soil Solarization

In soil solarization, Films made of transparent polyethylene (Figure 1) can raise soil temperature by up to 52 °C. By encasing solar heat or energy in polyethylene, soil solarization raises the temperature of the soil to a point where it is fatal. It is highly transparent to light in the spectrum of cm except for two absorbance bands around 7 and 14 µm in the infrared spectrum. It reduces heat convection and water evaporation from soil to the atmosphere. Raised beds oriented north to south, as opposed to east to west, will result in the most uniform soil heating. Improved pest control has results from more consistent heating. When there is no slope or when the slope is exposed to the south or southwest, solarization is most successful. Slopes that face north will have lower temperatures and less effective pest management. Plastic Integrity Tears or holes in the plastic sheets will negatively

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impact solarization. Entry onto or other disturbance of the plastic should be prohibited for both humans and animals.

Figure 1: Film made of transparent polyethylene

Preparation of Soil before Solarization

The first step to success is to properly prepare the soil before solarization. It is crucial that you finish the next steps at this point.

The selection of plastic plays a major role in soil solarization. Using of plastics directly influences the process of solarization. Employ a transparent, UV-stabilized plastic (polyethylene or polyvinyl chloride) tarp or sheeting that is 0.5 to 3 mils thick and sufficiently flexible to span the soil's surface. Where damage from strong winds or other comparable issues is expected, thicker plastic sheets (2 or more mils) should be utilized. To stop heat loss, holes or tears must be sealed right away with duct tape. Because not all types of soils respond to the soil solarization procedure identically, soil testing is crucial.

Steps Involved in Soil Solarization

1. Choosing the Location

The site for treatment should be devoid of clumps and plant residues and it should be well-ploughed. The use of a rototiller is optimal, but manual spading and raking can also be effective. Before solarization, the area must be cleared of weeds and debris. Tilling the ground aids in enhancing the heat penetration into the top 6 inches of the soil.

2. Selection and Application of Film for Solarization

Coloured films are not recommended as they absorb or reflect solar radiation instead of transmitting it, thereby reducing soil heating. Films that are thinner (0.5 to 1 mil) transmit more heat, but are more prone to tearing and have a shorter lifespan than thicker films. The film should be applied as close to the soil surface as possible to minimize air pockets and potential wind damage (Figure 2). The film should be securely anchored by burying the edges in trenches dug manually when treating small plots or gardens, or during bed formation and film application when using plasticulture. When treating linear rows (beds) with plasticulture, the beds are shaped and the film and drip tape are applied at the same time.

3. Covering the Soil with Transparent Plastic

Covering the area that needs to be treated is a clear plastic sheet or strip. Because the edges must be buried in

Figure 2: Use clear plastic to cover the soil

the soil, the plastic piece should be a bit bigger than the treated area.

4. Solarization Duration

For at least six weeks, the plastic should stay in its original position with all of its edges hidden. Following this time frame, the plastic can be taken out. If everything went according to plan, weeds and soil pests should disappear for three to four months. It is best to wait to plant until the transparent plastic has been removed because heat under it might kill seeds and plants.

Effects of Soil Solarization

1. Temperature of the Soil

Typically, the peak soil temperature achieved through solarization technology is observed around noon. However, the effectiveness of this technology significantly reduces at deeper soil levels when the temperature drops, usually during night time (Cohen and Rubin, 2007). The heat impact of soil solarization is most potent at the soil's surface and diminishes with increasing depth. Under typical field conditions, solarized soil can reach maximum temperatures of 108 to 131 °F (42 to 55 °C) at a depth of 2 inches (5 cm) and 90 to 99 °F (32 to 37 °C) at a depth of 18 inches (45 cm). Most soil pests can be effectively controlled in the top 4 to 12 inches (10-30 cm) of soil. Greenhouses or the use of two layers of plastic sheeting can be used to raise soil temperatures and heat the soil more deeply. A double layer of plastic with an air gap between them can raise soil temperatures by 2 to 10 °F over a single layer, simulating the greenhouse effect. But applying a double layer necessitates extra planning. In greenhouses, solar-heated soil can get as high as 140 °F (60 °C) at 4 inches (10 cm) and as low as 127 °F (53 °C) at 8 inches (20 cm). Soil solarized in black plastic nursery sleeves behind one or two clear plastic layers can reach temperatures as high as 70°C (158 °F). A single or double layer of clear plastic covering soil solarized in black plastic nursery sleeves can reach temperatures as high as 158 °F (70 °C). The primary mechanism involved in the disinfestation process by soil solarization is thermal killing (DeVay and Katan, 1991).

2. Weed Management

In the face of new challenges, particularly the rise of herbicide resistance and herbicide residues, weed scientists are turning to soil solarization as an optimal solution for pre-emergent weed control. The capacity of solarization to suppress a wide variety of weeds is one of its most obvious effects. While some weed species are relatively resistant to soil solarization, others are highly sensitive and need optimal circumstances (such as intense radiation, tightly-fitting plastic and sufficient soil moisture) to be effectively controlled. Winter annual weeds seem to be more vulnerable to solarization and treatment often results in weed control that lasts for more than a year. When it comes to crops grown in the fall, such onions, garlic, carrots, broccoli, other brassica crops and lettuce, soil solarization is especially useful in reducing weeds. But among the few winter annuals that are out of control is white sweet clover (*Melilotus alba*). Soil solarization is a relatively easy way to suppress summer annual weeds, even though they are less temperature sensitive than winter annuals.

3. Nematode Management

Soil solarization can be employed to manage a variety of nematode species (Table 1). Its ability to manage nematodes, however, is not always as strong as its ability to control weeds and fungal diseases. This is due to the fact that nematodes require yearly treatment for nematode management due to their relative mobility and ability to swiftly repopulate the soil.

Table 1: Impact of soil solarization on the occurrence and intensity of *Sclerotium rolfsii*-caused root collar rot, as well as on the first appearance and ultimate stand of (*Phaseolus vulgaris* L.) bean plantlets in crops produced following the removal of plastic mulch (Tomazeli *et al*., 2019)

Variable	Non-solarized soil	Solarized soil
1st Crop (1st Year)		
Incidence (%)	67.30	41.06
Severity (%)	21.52	1.91
Emergence (%)	76.41	78.13
Final Stand (%)	65.78	71.56
2nd Crop (1st Year)		
Incidence (%)	52.83	14.61
Severity (%)	16.84	1.57
Emergence (%)	81.42	81.48
Final Stand (%)	79.77	81.41
1st Crop (2nd Year)		
Incidence (%)	33.24	27.57
Severity (%)	6.89	4.01
Emergence (%)	73.52	78.44
Final Stand (%)	72.61	76.79

Above 12 inches (30 cm), solarization has the most control over the soil. Deeper in the soil profile nematodes could withstand solarization and even cause damage to plants with extensive root systems. Solarization typically offers enough nematode control for shallow-rooted, short-season plants to promote growth. For home gardeners and organic gardeners in particular, it is quite helpful. Incorporating solarization into an integrated nematode control system can also be advantageous. Solarization is capable of eliminating many types of nematodes, including pin, sting, cyst, spiral and root-knot nematodes. Notably, studies have reported that soil solarization has a positive effect on controlling root-knot nematodes in transplanted tomatoes.

4. Pathogen Management

While soil solarization eliminates many soil pests, numerous beneficial soil organisms can either withstand the process or quickly recolonize the soil afterward. Many fungi and bacteria that parasitize plant diseases and stimulate plant development are included in this group of helpful organisms, as are mycorrhizal fungi. Solarized soils may be more pathogen-resistant than non-solarized or fumigated soils due to this change in population dynamics. Although there hasn't been much research on how soil solarization affects earthworms, it's thought that they withdraw to deeper soil layers to escape the heat. In solarized soil, beneficial fungi can survive and even multiply, especially *Trichoderma*, *Talaromyces* and *Aspergillus* species. It is possible for mycorrhizal fungi to become less numerous in the upper soil profile because they are more heat-resistant than the majority of plant pathogenic fungi. Studies have shown that this decrease is not substantial enough to prevent them from colonizing host roots in soil that has been exposed to sunlight. Numerous important bacterial and fungal plant diseases can be controlled by soil solarization. These include *Clavibacter michiganensis*, which causes tomato canker; *Phytophthora cinnamomi*, which causes *Phytophthora* root rot; *Agrobacterium tumefaciens*, which causes crown gall disease; and *Streptomyces scabies*, which causes potato scab. *Verticillium dahliae*, which causes *Verticillium* wilt in various crops, is one of these. Controlling other fungi and bacteria, like *Pseudomonas solanacearum*, a soil-borne bacterium and several high-temperature fungi in the genera *Macrophomina*, *Fusarium* and *Pythium*, is more difficult with solarization. Between non-solarized and solarized plots in the second crop, there was a reduction in disease incidence of 52.83% to 14.61% and in severity of 16.84% to 1.57%, respectively. There was a decrease in disease intensity between treatments in the crop cultivated following the second solarization, however this decrease was not as significant. In the non-solarized and solarized plots, disease incidence dropped from 33.24% to 27.57% and severity dropped from 6.89% to 4.01%, respectively.

Conclusion

An eco-friendly, non-hazardous and user-friendly technique that lasts for several growth seasons or even a year is soil solarization. In comparison to chemical-based weed control, it offers a secure and effective substitute. When applied consecutively for two years, solarization can significantly improve crop yield and weed control. Both home gardeners and commercial crop producers can leverage solarization to substantially reduce weed populations in the long and short term. However, it's important to note that solarization eliminates all organisms, including beneficial ones. To counteract this, farmers and gardeners are advised to reintroduce beneficial organisms by incorporating compost into the soil after it has undergone solarization.

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