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Soil Solarization: An eco-friendly and effective disease management approach for soil borne diseases

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Abstract
The concept of managing soil borne pathogens has now changed. In past, control of these pathogens concentrated on eradication. Later it has been realized that effective control could be achieved by interrupting the disease cycle, plant resistance or the microbial balance leading to disease reduction below the economic injury level, rather than absolute control. The integrated pest management concept encompasses many elements.

Solarization can cause complex changes in physicochemical and biological properties such as, increasing the availability of mineral nutrients and soluble organic matter that affects soil micro flora and soil micro fauna population with high influences on the enzyme systems linked with the respiratory process. The soil micro fauna is the most active component in the soil system, assuring the main role in soil biogeochemical cycles.

Soil solarization for soil disinfestations has been well established and demonstrated under experimental or commercial conditions in a number of countries. The ultimate goal to develop this method for use under field conditions requires both basic and practical studies.

Keywords: Soil, Solarisation, Disease, Management

Introduction

More than 100 years after the introduction of soil disinfestations and more than 50 years after Sanford's classical publication on biological control our hungry world is still crying out for new methods for reducing crop losses caused by soil borne pathogens. We are always confronted with difficulties such as the appearance of new physiological races and development of resistance to pesticides while using conventional control methods. We are frustrated by the large gap between promising results in the green houses and failures in the fields. Different approaches have been applied for the management of diseases caused by plant pathogens *viz* sanitation, crop rotation, biological control, fungicidal application, breeding for disease resistance and soil disinfestations. The need for different methods of plant disease management required because none of them is perfect nor can anyone be used under all circumstances. The life cycles and survival of different pathogens may vary in different crop, thus requiring different management strategies. Therefore, any new method of disease management is improving our limited arsenal of control methods. This is particularly true with novel non chemical and eco-friendly approaches which are needed to replace hazardous chemicals.

In Israel, extension workers and growers suggested that the intensive heating that occurs in mulched soil might be used for disease control. By mulching the soil with transparent polyethylene sheets in the hot season prior to planting, a team of Israeli workers developed a solar heating approach for soil disinfestation (Katan, 1995) [9]. The literal meaning of term solarisation refers to a chemical change in glass, caused by sunlight or another ultraviolet radiation, which causes a photochemical reaction resulting in a decrease in ultraviolet transmission in addition to a noticeable colour change (Koller, 1965) [11]. In other way, Soil solarization refers to disinfestations of soil by the heat generated from trapped solar energy (Katan, 1987) [8]. The basic principle of soil solarization is to elevate the temperature in a moist soil to a lethal level that directly affects the viability of certain organisms. The heating process also induces other environmental and biological changes in the soil that indirectly affect soil-borne pests as well as survival of beneficial organisms (Katan, 1981) [7]. Soil solarization is an environment friendly method of using solar radiation for controlling soil borne plant pathogens by mulching the soil and covering it with tarp, usually with a transparent polyethylene cover for four weeks or more when irradiation and temperatures are high, to increase the maximal temperatures to a level lethal to pest. This effect is successful especially to control those plant pathogens and pests that are heat sensible and unable to survive at temperatures above

37–40 °C. Furthermore, soil pasteurization by solar heating gives positive effects against a broad number of seed weeds affecting crops cultivation, it is also very effective in managing the soil inhabitant insect pests, weeds, nematodes, plant pathogenic fungi and bacteria and also results in an increased growth response (IGR) of plants (Katan, 1981) [7].
Environmental factors such as soil temperature and soil moisture are known to have pronounced influence on the dynamics of soil respiration (Scopa and Dumontet, 2007) [17].
Use of this method has been reported to reduce the population of many soil borne pathogens including fungi bacteria and nematodes as well as weeds (Pullman *et al*., 1981; Katan *et al*., 1983; Barbercheck *et al*; 1986; Verma *et al*; 2005) [12, 10, 3, 19].

Mechanism of disease management

Reduction in disease incidence occurring in solarized soils, results from the effects exerted on each of the three living components involved in disease (host, pathogen, and soil microbiota) as well as the physical and chemical environment which, in turn affects the activity and interrelationships of the organisms. Although these processes occur primarily during solarization, they may continue to various extents and in different ways, after the removal of the polyethylene sheets and planting. The most pronounced effect of soil mulching with polyethylene is a physical one, i.e. an increase in soil temperatures, for several hours of the day. However, other accompanying processes such as shifts in microbial populations, changes in chemical composition and physical structure of the soil, high moisture levels maintained by the mulch, and changes in gas composition of the soil, should also be considered while analyzing mechanisms of disease control. The following equation proposed by Baker (1968) [2], for relating the various factors involved in biological control, should be adopted for this analysis:
Disease severity =inoculum potential x disease potential, where inoculum potential is the energy available for colonization of a substrate (infection court) at the surface and disease potential is the ability of the host to contract disease. More specifically the equation becomes:
Disease severity = (inoculum density x capacity) x (proneness x susceptibility), where capacity is the effect of the environment on energy for colonization, and proneness is the effect of the environment on the host. Of these four components, inoculum density (ID) is the one most affected by solarization either through the direct physical effect of the heat or by microbial processes induced in the soil. The other components, however (except for susceptibility which is genetically determined) might also be affected. Microbial processes, induced in the soil by solarization, may contribute to disease control, since the impact of any lethal agent in the soil extend beyond the target organisms. If induced by solarization, biological control may affect the pathogen by increasing its vulnerability to soil microorganisms or increasing the activity of soil microorganisms toward pathogen or plant, which will finally lead to a reduction in disease incidence, pathogen survivability, or both. Thus both short and long term effects might be expected. Biological control may operate at any stage of of pathogen survival or disease development during or after solarization, through antibiosis, lysis, parasitism, or competition.
Combining solarization with other methods such as pesticides or biocontrol agents improves disease control. Whenever a pathogen is weakened by heating, even reduced dosages might suffice for improved control combining with biocontrol agents, organic amendments, etc.

Advantages

Soil solarization as a disinfestations method, has potential advantages. It is a non chemical method which is not hazardous to the user and does not involve substances toxic to the consumer, to the host plant or to other organisms. In the right perspective it is less expensive than other methods. This technology can easily be transmitted to the ordinary farmers and can be applied in large areas manually and mechanically. Thus, it is suitable for both developed and developing countries. It may have a long term effect, since effective disease control lasts for more than one season. This method has the characteristics of an integrated control, since physical, chemical and biological mechanisms are involved and because the control of a varieties of pests is achieved.

Limitations

Solarization involves limitations, difficulties and potential negative side effects. It can only be used in regions where the climate is suitable (hot) and the soil is free of crops for about one month or more at a time of tarping with PE sheets.

- It requires longer time for process and climate dependent.
- There are geographical limitations on where the method can be used in terms of solar radiation availability.
- It is too expensive for some crops and ineffective in the control of certain diseases.
- Heat tolerant pathogens might develop after repeated application, though selection for tolerance to lethal agents is not likely to develop with disinfestation methods which are not target specific.
- Another possibility would be an increase in pathogen population due to a harmful effect on its antagonists.
- It is difficult to protect PE sheets from wind and animals.

Disease Management

Soil solarization has been demonstrated to control diseases caused by many fungal pathogens such as *Rhizoctonia solani*, *Fusarium* spp., *Pythium* spp., *Phytophthora* spp., *Verticillium* spp., *Bipolaris sorokiniana*, *Plasmodiophora brassicae*, *Sclerotium rolfsii* etc. in many crops (Katan *et al*., 1983; Abdul *et al*., 1995; Raoof and Rao, 1997; Puri, 2016) [10, 16, 13].
Soil solarization has also been shown to significantly decrease the population of disease causing Agrobacteria and *Pseudomonas* (Raio *et al*., 1997; Chellemi *et al*., 1994) [14, 4].
Many nematode diseases caused by *Meloidogyne* spp., *Heterodera* spp. etc.have been successfully controlled by soil solarization (Rao and Krishnappa, 1995; Grinstein *et al*., 1995) [15, 6].

Beneficial side effects

Control of weeds

Solarization results in an effective weed control lasting in some cases for more than two or three seasons (Abdel Rahim *et al*., 1988; Verma *et al*., 2005) [1, 19]. In general most of the annual and many perennial weeds have been found to be effectively controlled.

Increased growth response

The increased growth response of plants in solarized soil is a well-documented phenomenon and has been verified both in green house experiments and under field conditions (Katan, 1987; Chen *et al*., 1991; Singh, 2008) [8, 5, 18].

Conclusion

Soil solarization should not be regarded as a universal method but rather as an additional one which, if used correctly, can reduce pest damage safely, effectively and economically. Population of total fungi, bacteria, actinomycetes, decreased drastically due to solarization in all the conditions as compare to non-solarized soils which indicates that this technique can be an effective physical strategy in controlling soil borne pathogens. Solarization is a new additional option to use and include suitably in such IPM programs. Its scope and rate of dissemination in the future will depend on our capacity to both weigh its pros and cons and use it effectively.

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