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Unleashing the Power of Soil Solarization: Optimizing Crop Growth and Yield

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ABSTRACT: Soil solarization is a non-chemical environmentally friendly method for controlling pests using solar power to increase the soil temperature to levels at which many soil-borne plant pathogens will be killed or greatly weakened.[1] Soil solarization is used in warm climates on a relatively small scale in gardens and organic farms. Soil solarization weakens and kills fungi, bacteria, nematodes, and insect and mite pests along with weeds in the soil by mulching the soil and covering it with a tarp, usually with a transparent polyethylene cover to trap solar energy. This energy causes physical, chemical, and biological changes in the soil community.[2] Soil solarization is dependent upon time, temperature, and soil moisture.[1] It may also be described as methods of decontaminating soil or creating suppressive soils by the use of sunlight

KEYWORDS: soil solarization, environment friendly, pest control, decontamination, power, optimizing crop growth, yield

I.INTRODUCTION

Soil solarization is a hydrothermal process of disinfecting the soil of pests, accomplished by solar power (referred to as solar heating of the soil in early publications) and is relatively a new soil disinfestation method, first described in extensive scientific detail by Katan in 1976.[3] The mode of action for soil solarization is complex and involves the use of heat as a lethal agent for soil pests from the use of transparent polyethylene tarps.[4] To increase the effectiveness of solar heating requires optimal seasonal temperatures, mulching during high temperatures and solar irradiation, and moisture soil conditions.[5] Soil temperatures are lower when decreasing in soil depth and it is necessary to continue the mulching process to control for pathogens. Soil solarization practices requires soil temperatures reach 35-60 degrees Celsius (95 to 140°F), which kills pathogens at the top 30 centimeters of soil.[6] Solarization does not sterilize the soil completely. Soil solarization enhances the soil towards promoting beneficial microorganism.[1] Soil solarization creates a beneficial microbe community by killing up to 90% of pathogens.[6] More specifically, a study reported after eight days of solarization 100% of V. dabliae (a fungus that causes farm crops to wilt and die) was killed at a depth of 25 centimeters.[4] Soil solarization causes a decrease in beneficial microbes, however beneficial bacteria like the Bacillus species are able to survive and flourish under high temperatures in solarized soils.[6] Other studies have also reported an increase in Trichoderma harzianum (fungicide) after solarization.[6] Soil solarization allows for the recolonization of competitive beneficial microbes by creating a favorable environment conditions.[7] The number of beneficial microbes increases over time and makes solarized soils more resistant to pathogens.[6] The success of solarization is not only due to the decrease in soil pathogens, but also to the increase in beneficial microbes such as Bacillus, Pseudomonas, and Talaromyces flavus.[1] Soil solarization has been shown to suppress soil pathogens and cause an increase in plant growth. Suppressed soils promote rhizobacteria and have shown to increase total dry weight in sugar beets by 3.5 times.[8] Also the study showed that plant growth promoting rhizobacteria on sugar beets treated with soil solarization increased root density by 4.7 times.[8] Soil solarization is an important agricultural practice for ecologically friendly soil pathogen suppression. A 2008 study used a solar cell to generate an electric field for electrokinetic (EK) remediation of cadmium-contaminated soil. The solar cell could drive the electromigration of cadmium in contaminated soil, and the removal efficiency that was achieved by the solar cell was comparable with that achieved by conventional power supply.[9]

In Korea, various remediation methods of soil slurry and groundwater contaminated with benzene at a polluted gas station site were evaluated, including a solar-driven, photocatalyzed reactor system along with various advanced oxidation processes (AOP). The most synergistic remediation method incorporated a solar light process with TiO_2 slurry and H_2O_2 system, achieving 98% benzene degradation, a substantial increase in the removal of benzene.[10]

In 1939, Groashevoy, who used the term "solar energy for sand disinfection", controlled Thielaviopsis basicola upon heating the sand by exposure to direct sunlight

Soil solarization is the third approach for soil disinfestation; the two other main approaches, soil steaming and fumigation; were developed at the end of the 19th century. The idea of solarization was based on observations by extension workers and farmers in the hot Jordan Valley, who noticed the intensive heating of the polyethylene-mulched soil. The involvement of biological control mechanisms in pathogen control and the possible implications were indicated in the first publication, noticing the very long effect of the treatment. In 1977, American scientists from the University of California at Davis reported the control of Verticillium in a cotton field, based on studies started in 1976, thus denoting, for the first time, the possible wide applicability of this method.

The use of polyethylene for soil solarization differs in principle from its traditional agricultural use. With solarization, soil is mulched during the hottest months (rather than the coldest, as in conventional plasticulture which is aimed at protecting the crop) in order to increase the maximal temperatures in an attempt to achieve lethal heat levels.

In the first 10 years following the influential 1976 publication, soil solarization was investigated in at least 24 countries[11] and has been now been applied in more than 50, mostly in the hot regions, although there were some important exceptions. Studies have demonstrated effectiveness of solarization with various crops, including vegetables, field crops, ornamentals and fruit trees, against many pathogens, weeds and a soil arthropod. Those pathogens and weeds which are not controlled by solarization were also detected. The biological, chemical and physical changes that take in solarized soil during and after the solarization have been investigated, as well as the interaction of solarization with other methods of control. Long-term effects including biological control and increased growth response were verified in various climatic regions and soils, demonstrating the general applicability of solarization. Computerized simulation models have been developed to guide researchers and growers whether the ambient conditions of their locality are suitable for solarization.

Studies of the improvement of solarization by integrating it with other methods or by solarizing in closed glasshouses, or studies concerning commercial application by developing mulching machines were also carried out.

The use of solarization in existing orchards (e.g. controlling Verticillium in pistachio plantations) is an important deviation from the standard preplanting method and was reported as early as 1979.

II.DISCUSSION

Soil contamination, soil pollution, or land pollution as a part of land degradation is caused by the presence of xenobiotic (human-made) chemicals or other alteration in the natural soil environment. It is typically caused by industrial activity, agricultural chemicals or improper disposal of waste. The most common chemicals involved are petroleum hydrocarbons, polynuclear aromatic hydrocarbons (such as naphthalene and benzo(a)pyrene), solvents, pesticides, lead, and other heavy metals. Contamination is correlated with the degree of industrialization and intensity of chemical substance. The concern over soil contamination stems primarily from health risks, from direct contact with the contaminated soil, vapour from the contaminants, or from secondary contamination of water supplies within and underlying the soil.[1] Mapping of contaminated soil sites and the resulting cleanups are time-consuming and expensive tasks, and require expertise in geology, hydrology, chemistry, computer modeling, and GIS in Environmental Contamination, as well as an appreciation of the history of industrial chemistry.[2]

In North America and Western Europe the extent of contaminated land is best known, with many of countries in these areas having a legal framework to identify and deal with this environmental problem. Developing countries tend to be less tightly regulated despite some of them having undergone significant industrialization.

Soil pollution can be caused by the following (non-exhaustive list) :

- Microplastics
- Oil spills
- Mining and activities by other heavy industries
- Accidental spills may happen during activities, etc.
- Corrosion of underground storage tanks (including piping used to transmit the contents)
- Acid rain
- Intensive farming
- Agrochemicals, such as pesticides, herbicides and fertilizers
- Petrochemicals
- Industrial accidents
- Road debris

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- Construction activities
- Exterior lead-based paints
- Drainage of contaminated surface water into the soil
- Ammunitions, chemical agents, and other agents of war
- Waste disposal
  - Oil and fuel dumping
  - Nuclear wastes
  - Direct discharge of industrial wastes to the soil
  - Discharge of sewage
  - Landfill and illegal dumping
  - Coal ash
  - Electronic waste
  - Contaminated by rocks containing large amounts of toxic elements.
  - Contaminated by Pb due to vehicle exhaust, Cd, and Zn caused by tire wear.
  - Contamination by strengthening air pollutants by incineration of fossil raw materials.

The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead, and other heavy metals.

Any activity that leads to other forms of soil degradation (erosion, compaction, etc.) may indirectly worsen the contamination effects in that soil remediation becomes more tedious.

Historical deposition of coal ash used for residential, commercial, and industrial heating, as well as for industrial processes such as ore smelting, were a common source of contamination in areas that were industrialized before about 1960. Coal naturally concentrates lead and zinc during its formation, as well as other heavy metals to a lesser degree. When the coal is burned, most of these metals become concentrated in the ash (the principal exception being mercury). Coal ash and slag may contain sufficient lead to qualify as a "characteristic hazardous waste", defined in the US as containing more than 5 mg/L of extractable lead using the TCLP procedure. In addition to lead, coal ash typically contains variable but significant concentrations of polynuclear aromatic hydrocarbons (PAHs; e.g., benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(cd)pyrene, phenanthrene, anthracene, and others). These PAHs are known human carcinogens and the acceptable concentrations of them in soil are typically around 1 mg/kg. Coal ash and slag can be recognised by the presence of off-white grains in soil, gray heterogeneous soil, or (coal slag) bubbly, vesicular pebble-sized grains.

Treated sewage sludge, known in the industry as biosolids, has become controversial as a "fertilizer". As it is the byproduct of sewage treatment, it generally contains more contaminants such as organisms, pesticides, and heavy metals than other soil.[3]

In the European Union, the Urban Waste Water Treatment Directive allows sewage sludge to be sprayed onto land. The volume is expected to double to 185,000 tons of dry solids in 2005. This has good agricultural properties due to the high nitrogen and phosphate content. In 1990/1991, 13% wet weight was sprayed onto 0.13% of the land; however, this is expected to rise 15 fold by 2005. Advocates[who?] say there is a need to control this so that pathogenic microorganisms do not get into water courses and to ensure that there is no accumulation of heavy metals in the top soil.[4]

III.RESULTS

Solar irradiance is the power per unit area (surface power density) received from the Sun in the form of electromagnetic radiation in the wavelength range of the measuring instrument. Solar irradiance is measured in watts per square metre (W/m^2) in SI units.

Solar irradiance is often integrated over a given time period in order to report the radiant energy emitted into the surrounding environment (joule per square metre, J/m^2) during that time period. This integrated solar irradiance is called solar irradiation, solar exposure, solar insolation, or insolation.

Irradiance may be measured in space or at the Earth's surface after atmospheric absorption and scattering. Irradiance in space is a function of distance from the Sun, the solar cycle, and cross-cycle changes.[2] Irradiance on the Earth's surface additionally depends on the tilt of the measuring surface, the height of the Sun above the horizon, and atmospheric conditions.[3] Solar irradiance affects plant metabolism and animal behavior.[4]

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The study and measurement of solar irradiance have several important applications, including the prediction of energy generation from solar power plants, the heating and cooling loads of buildings, climate modeling and weather forecasting, passive daytime radiative cooling applications, and space travel.

There are several measured types of solar irradiance.

- Total Solar Irradiance (TSI) is a measure of the solar power over all wavelengths per unit area incident on the Earth's upper atmosphere. It is measured perpendicular to the incoming sunlight.[3] The solar constant is a conventional measure of mean TSI at a distance of one astronomical unit (AU).
- Direct Normal Irradiance (DNI), or beam radiation, is measured at the surface of the Earth at a given location with a surface element perpendicular to the Sun.[6] It excludes diffuse solar radiation (radiation that is scattered or reflected by atmospheric components). Direct irradiance is equal to the extraterrestrial irradiance above the atmosphere minus the atmospheric losses due to absorption and scattering. Losses depend on time of day (length of light's path through the atmosphere depending on the solar elevation angle), cloud cover, moisture content and other contents. The irradiance above the atmosphere also varies with time of year (because the distance to the Sun varies), although this effect is generally less significant compared to the effect of losses on DNI.
- Diffuse Horizontal Irradiance (DHI), or Diffuse Sky Radiation is the radiation at the Earth's surface from light scattered by the atmosphere. It is measured on a horizontal surface with radiation coming from all points in the sky excluding circumsolar radiation (radiation coming from the sun disk).[6][7] There would be almost no DHI in the absence of atmosphere.[6]
- Global Horizontal Irradiance (GHI) is the total irradiance from the Sun on a horizontal surface on Earth. It is the sum of direct irradiance (after accounting for the solar zenith angle of the Sun z) and diffuse horizontal irradiance:[8]
- Global Tilted Irradiance (GTI) is the total radiation received on a surface with defined tilt and azimuth, fixed or sun-tracking. GTI can be measured[7] or modeled from GHI, DNI, DHI.[9][10][11] It is often a reference for photovoltaic power plants, while photovoltaic modules are mounted on the fixed or tracking constructions.
- Global Normal Irradiance (GNI) is the total irradiance from the sun at the surface of Earth at a given location with a surface element perpendicular to the Sun.

Plant growth-promoting rhizobacteria (PGPR) were first defined by Kloepper and Schroth[6] to be soil bacteria that colonize the roots of plants following inoculation onto seed and that enhance plant growth.[7] The following are implicit in the colonization process: ability to survive inoculation onto seed, to multiply in the spermosphere (region surrounding the seed) in response to seed exudates, to attach to the root surface, and to colonize the developing root system.[8] The ineffectiveness of PGPR in the field has often been attributed to their inability to colonize plant roots.[3][9] A variety of bacterial traits and specific genes contribute to this process, but only a few have been identified. These include motility, chemotaxis to seed and root exudates, production of pili or fimbriae, production of specific cell surface components, ability to use specific components of root exudates, protein secretion, and quorum sensing. The generation of mutants altered in expression of these traits is aiding our understanding of the precise role each one plays in the colonization process.[10][11]

Progress in the identification of new, previously uncharacterized genes is being made using nonbiased screening strategies that rely on gene fusion technologies. These strategies employ reporter transposons[12] and in vitro expression technology (IVET)[13] to detect genes expressed during colonization.

Using molecular markers such as green fluorescent protein or fluorescent antibodies, it is possible to monitor the location of individual rhizobacteria on the root using confocal laser scanning microscopy.[3][14][15] This approach has also been combined with an rRNA-targeting probe to monitor the metabolic activity of a rhizobacterial strain in the rhizosphere and showed that bacteria located at the root tip were most active.[16]

Implications

Pest control is the regulation or management of a species defined as a pest; such as any animal, plant or fungus that impacts adversely on human activities or environment.[1] The human response depends on the importance of the damage done and will range from tolerance, through deterrence and management, to attempts to completely eradicate the pest. Pest control measures may be performed as part of an integrated pest management strategy.

In agriculture, pests are kept at bay by mechanical, cultural, chemical and biological means.[2] Ploughing and cultivation of the soil before sowing mitigate the pest burden, and crop rotation helps to reduce the build-up of a certain pest species.

Concern about environment means limiting the use of pesticides in favour of other methods. This can be achieved by monitoring the crop, only applying pesticides when necessary, and by growing varieties and crops which are resistant to pests. Where possible, biological means are used, encouraging the natural enemies of the pests and introducing suitable predators or parasites.[3]

In homes and urban environments, the pests are the rodents, birds, insects and other organisms that share the habitat with humans, and that feed on and/or spoil possessions. Control of these pests is attempted through exclusion or quarantine, repulsion, physical removal or chemical means.[4] Alternatively, various methods of biological control can be used including sterilisation programmes.

Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaics (PV) or indirectly using concentrated solar power. Photovoltaic cells convert light into an electric current using the photovoltaic effect.[2] Concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight to a hot spot, often to drive a steam turbine.

Photovoltaics were initially solely used as a source of electricity for small and medium-sized applications, from the calculator powered by a single solar cell to remote homes powered by an off-grid rooftop PV system. Commercial concentrated solar power plants were first developed in the 1980s. Since then, as the cost of solar electricity has fallen, grid-connected solar PV systems have grown more or less exponentially. Millions of installations and gigawatt-scale photovoltaic power stations continue to be built, with half of new generation capacity being solar in 2020.[3]

In 2020 solar generated 4.5% of the world's electricity,[4] compared to 1% in 2015 when the Paris Agreement to limit climate change was signed.[5] Along with onshore wind, in most countries the cheapest levelised cost of electricity for new installations is utility-scale solar.[6][7]

Almost half the solar power installed in 2020 was rooftop.[4] Much more low-carbon power, such as solar, is urgently needed to limit climate change, but the International Energy Agency said in 2020 that more effort was needed for grid integration and the mitigation of policy, regulation and financing challenges.[8]

IV.CONCLUSIONS

Geography affects solar energy potential because different locations receive different amounts of solar radiation. In particular, with some variations, areas that are closer to the equator generally receive higher amounts of solar radiation. However, the use of photovoltaics that can follow the position of the Sun can significantly increase the solar energy potential in areas that are farther from the equator.[9] Time variation affects the potential of solar energy, because during the night there is little solar radiation on the surface of the Earth for solar panels to absorb. This limits the amount of energy that solar panels can absorb in one day. Cloud cover can affect the potential of solar panels because clouds block incoming light from the Sun and reduce the light available for solar cells.

Besides, land availability has a large effect on the available solar energy because solar panels can only be set up on land that is otherwise unused and suitable for solar panels. Roofs are a suitable place for solar cells, as many people have discovered that they can collect energy directly from their homes this way. Other areas that are suitable for solar cells are lands that are not being used for businesses, where solar plants can be established.[9]

With the increasing efficiencies of thin film solar, installing them on metal roofs has become cost competitive with traditional Monocrystalline and Polycrystalline solar cells. The thin film panels are flexible and run down the standing seam metal roofs and stick to the metal roof with Adhesive, so no holes are needed to install. The connection wires run under the ridge cap at the top of the roof. Efficiency ranges from 10-18% but only costs about $2.00-$3.00 per watt of installed capacity, compared to Monocrystalline which is 17-22% efficient and costs $3.00-$3.50 per watt of installed capacity. Thin film solar is light weight at 7-10 ounces per square foot. Thin film solar panels last 10–20 years[22] but have a quicker ROI than traditional solar panels, the metal roofs last 40–70 years before replacement compared to 12–20 years for an asphalt shingle roof.[23][24]

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