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INTERNATIONAL ADVANCED RESEARCHES
and
ENGINEERING JOURNAL

Journal homepage: www.dergipark.gov.tr/iarej

International
Open Access

Volume 02
Issue 02

August, 2018

e-ISSN: 2618-575X

Review Article

Use of solar panels in greenhouse soil disinfection

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ARTICLE INFO

Article history:
Received 23 March 2018
Revised 31 May 2018
Accepted 11 June 2018

Keywords:
Solar energy
Solar panel
Greenhouse
Soil disinfection

ABSTRACT

Restrictions on pesticides used in greenhouses around the world have led investigators and employees to take advantage of renewable energy sources in agriculture. In this study, solar panels (photovoltaic battery) and their us in soil disinfection in greenhouses have been discussed as a use of renewable energy sources in agriculture. Soil disinfection can be done by placing the resistance wires with low electricity consumption (25 W m^{-1}) and increasing the soil temperature to the required levels by using the electricity obtained from the solar panels. Thus, soil disinfection can be achieved by increasing the soil temperature. With high temperatures the duration of soil disinfection can be shortened considerably. Solarization application made with transparent plastic covering that is covered on greenhouse soil will also increase the success of disinfection. These practices are implemented in summer, when there is no production in the greenhouse and the weather is hot. The use of solar panels in the autumn, winter and spring months of production in the greenhouse will be for different purpose. The resulting electrical energy can also provide the energy of the ventilators used for forced ventilation of the greenhouse. It can also be used to meet the energy needs of some tools and equipment to be used in the lighting of the greenhouse.

1. Introduction

Major part of energy sources utilized worldwide are fossil energy sources such as natural gas and petroleum which lead to environmental issues. Utilization of ecofriendly renewable energy sources instead of fossil fuels, which introduce greenhouse gases and are running low in reserves and are leading to significant issues in the atmosphere, are becoming common place. Moreover, numerous studies on renewable energy resources are conducted in many counties and they are supported by the governments.

Sun is the world's leading, renewable and infinite source of energy. There are other sources of energy such as wind, sea waves, warm ocean currents, and biomass, however, they are possible solar energy. Sunlight consists of small energy packets called photons. Photons received from the sun every minute transmit energy in the amount which meets the world's annual energy requirement [2].

It is possible to generate heat and electric power directly from solar power [27], [3]. As seen in Chart 1, there is too much solar energy according to the renewable energy sources worldwide [14]. What makes solar energy valuable compared to other renewable energy sources is that it is ready-to-use worldwide.

Table 1. Worldwide renewable energy sources and their potentials [16]

Source of Energy	**Energy Potential (TW)**
Wind energy	2-4
Hydroelectric energy	0,5
Geothermal energy	12
Tide and ocean currents energy	2
Solar energy	120.000

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Note: This study was presented at International Advanced Researches and Engineering Congress 2017 (IAREC'17)

(TW=terawatt=$1x10^{12}$ watt)

European Commission for Energy has adopted a resolution to increase renewable energy sources utilized throughout the Europe. With this resolution, it is decided that the share of renewable energy sources utilized in European countries shall be increased up to %20 in overall utilized energy until 2020 [21].

EPDK (Energy Market Regulatory Authority) has promoted utilization of solar energy in 38 cities in Turkey. Konya is in the first place with 92 mW (megawatts) of investment. It is declared that 85% discount will be applied to lease servitude right of use permit fees for the first ten years of investments to be made to such cities [5].

1.1. Solar Energy Potential of Turkey

It is possible to consider Turkey to be fortunate in terms of solar energy compared to many countries. Sunshine duration varies based on seasons and regions. Our country is divided into three categories in west-east direction in terms of total solar radiation. While the radiation level is 1400-1500 kWh $m^{-2}year^{-1}$in Marmara and Black Sea regions, it is 1500-1600 kWh $m^{-2}year^{-1}$in Aegean, inner regions of Central Anatolia, and northern parts of Eastern Anatolia, and around 1600-1750 kWh $m^{-2}year^{-1}$in Mediterranean and Southeastern Anatolia [5].

Sunshine durations in our country vary seasonally. Daily sunshine duration is approximately 5 hours in winter, 7 hours in spring, and 11 hours in summer months [4].

It is determined that annual average sunshine duration of Turkey is 2640 hours (daily average is 7,2 hours), and total average radiant intensity is 1311 kWh m^{-2} $year^{-1}$ (total daily average is 3,6 kWh $m^{-2}day^{-1}$) [19]. Total average radiant intensity for Tekirdağ province in which this study is conducted is 1281,2 kWh $m^{-2}year^{-1}$, and very close to Turkey average (97,7%). Sonar panels are required to generate electric power directly from sunlight, and solar collectors are required to generate thermal energy from the sun.

1.2. Solar Panels

It is mentioned that solar panels can be used to generate electric power economically in rural areas where there is no electrical network [11]. Therefore, electricity usage in agricultural establishments, greenhouses, and livestock establishments in rural areas become widespread. They provide the electrical energy required by greenhouses to be used in lighting, ventilation, cooling, disinfection and electronic measuring instruments.

Solar panel is a photovoltaic equipment, which is composed of solar cells and converts sunlight directly to electric current. Solar cells are made from organic and inorganic bases. Generally inorganic based solar cells have a wider area of usage due to their 15-20% yield and higher efficiency [15].

Solar cells (photovoltaic cells) are semiconductors which convert the sunlight received by the surface directly to electrical energy. Materials such as silicon, gallium arsenide, cadmium wires are the optimum ones for building solar cells among many other semiconductors. Silicon is the most commonly used material. In order to use silicon as a solar cell, it must be doped with phosphorus and aluminum. Surfaces of the solar cells to be made of such material may be rectangular, square, and round. Surfaces typically have an area of 100 cm^2 and thickness of 0,2-0,4 mm. Solar cells are connected in parallel or series in order to boost the output power, and solar panels are produced by installing them on a surface [6].

Turkey is located in 36˚-42˚ north latitudes and 26˚-45˚ east meridians, and therefore solar panels must be installed with an angle of 60˚. Thus, solar panels in a solar energy system to be installed in our country must be directed to the sun with angle of 60˚ from the ground plane [7].

Efficiency rates of solar cells are determined according to 25˚C. System efficiency is decreased due to reasons such as high or low air temperatures, dusts, droppings (such as from birds) casting a shadow, and sunlight angle of incidence not being perpendicular [4].

This study lays emphasis on utilizing the sun as one of the renewable sources of energy in greenhouses in a different manner. Utilization of the electrical energy generated by solar panels in greenhouse soil disinfection is studied. Temperature generated by utilizing the generated electrical energy in resistance wires laid in the soil and solarization method are utilized together, and their effects on greenhouse soil disinfection are determined.

1.3. Solarization and Disinfection in Greenhouses

Greenhouses are not heated when the air temperature is low because such practice increases the operational costs extremely and causes the production to be expensive. Therefore, in general solar energy is used as the source of energy in greenhouse farming [28].

Greenhouse internal temperature and humidity are typically higher in greenhouses with monoculture practice. Low greenhouse soil air and high soil humidity due to irrigation causes rapid growth and spread of all kinds of diseases and pests in the greenhouse. The method which decreases soil diseases and impacts of pests on the soil to some extent for a healthy, efficient and quality production in greenhouses is disinfection.

Since the soil is porous and has a three-phase structure, the transfer of heat is quite slow. The heat transfer within the soil greatly depends on the structure of the soil as well as the water and air content of the soil [10]. Because of this, increasing the water content of the soil will help transfer of heat within the soil. It is desirable to increase the water content by watering the soil during solarization. When the water content of the soil come close to saturation the heat transfer of the soil increases [22;23;25].

Disease factors causing damages in cultivated plants and most of the nematodes are found in the soil. Physical and chemical control of these soil borne factors found in greenhouse soils is possible. Greenhouse soil is heated up to a specific temperature using various methods in physical disinfection. Certain extremely toxic chemicals (pesticides) are applied to the soil in chemical disinfection. This method is extremely harmful to both environment and human health, and negatively affects the natural balance. These chemicals may return to people in one form or another [19]. In addition, they have many undesirable effects such as resistance against disease, pests and weeds [14]. Today, chemical pesticides must be used in a conscious and controlled manner in order to ensure sustainable agricultural production and protect both human health and environmental. Chemical pesticide use must be restricted as much as possible by taking measures in this field [24], [12].

Use and production of MeBr, as one of the extremely toxic agricultural pesticides used in soil disinfection, is prohibited worldwide. Accordingly, studies are conducted on physical methods in which high temperatures are applied in soil pests control. It is found out that soil solarization applications are effective in removal of pests from greenhouse soil [17], [18]. In solarization method, soil surface is covered with a plastic cover, and sunlight ensures that the temperature of the soil under such cover increases.

Solarization is performed for heating the soil by using the solar energy in summer months when exterior temperature is high and the greenhouse is empty. This method has advantages such as being cost effective and having no adverse effects for the environment. However, minimum duration of application is long as 3-4 weeks [13].

Diseases and pests in the soil must be determined and soil temperature must be increased accordingly in application of physical disinfection methods. Temperature must be 71-77^{o}C for greenhouse soil disinfection. Increasing the temperature too much may cause the beneficial soil bacteria to lose their validity as well [26].

In consideration of the daily global intensity values of sunshine in Thrace Region, it is possible to generate electrical energy by using the solar panels system in the region. It is possible to make soil disinfection more effective by using such generated electrical energy in the resistance wires laid in the soil. Hazardous effects of the chemicals used in disinfection will be avoided and the cost will be eliminated by using this system. Generalizing the system especially in the cultivated plants with higher economic return will make it a more economic production method in addition to the consumer health and reduction of chemical inputs.

2. Material and Method

2.1. General Characteristics of Research Area

Research area is the Thrace Region located in northwest of Turkey and city center of Tekirdağ province. Thrace Region is located on European continent of Turkey between 26^{o}-29^{o} east longitudes and 40^{o}-42^{o} north latitudes. Moreover, Edirne, Kırklareli and Tekirdağ provinces are entirely, and European sides of Çanakkale and İstanbul provinces are located in this region. Location of the Research area is shown in Figure 1.

Figure 1. Research area location [8]

Tekirdağ province, in which the study is conducted, is located between 26^{o}41′-28^{o}10′ east longitudes and 40^{o}35′-41^{o}35′ north latitudes. Surface area is approximately 621788 ha. Land structure of Tekirdağ is slightly rugged, and the geological structure is very young. Current appearance of the province was formed in the quaternary period. Tekirdağ has sub-humid climate. Weather is windy in summer and winter months. Prevailing and continuous winds are northeaster and southwester [1].

Tekirdağ province is eligible for greenhouse cultivation in terms of climate, soil and water resources. There are good marketing opportunities for grown produce. It is very close to İstanbul, a major consumption center, and just 135 km's away [28].

2.2. Solar Panel System Design

A system to be installed using solar panels for greenhouse soil disinfection (Figure 2) may consist of

solar panels, battery set, battery charging regulator, inverter, auxiliary electronic circuits, and resistance wires for heating the soil [4].

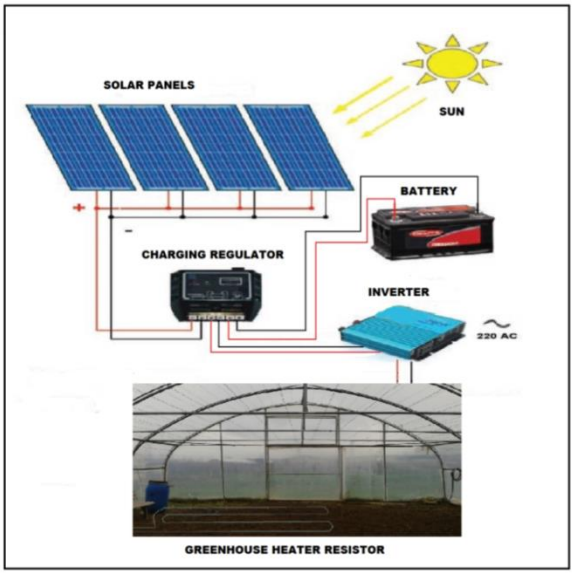

Figure 2. Components of greenhouse soil disinfection system with solar panels

Number of photovoltaic (solar) panels which covert sunlight to electrical energy are determined based on the amount of energy required. While panel efficiencies vary based on the type of panel, which are usually 15-20%. As previously mentioned, certain external factors decrease panel efficiency. Therefore, it is better to use panels with a capacity slightly higher than the calculated power requirement.

Battery set is added to the system for storing the electrical energy. Such battery set is used to provide energy and run the system when there is no solar energy.

Batter charging regulator regulates the current coming from the solar panel, and prevents the battery from overcharging or completely discharging. Thus, battery damage is avoided. Charging regulator disconnects the incoming current or the current drawn by the load based on the battery state.

Inverter is used in applications requiring alternating current in order to convert the direct current power generated by the panels to alternating current power. There are typically two types of inverters with and without full sinus output. Inverter with full sinus output capability must be used for systems with precision instruments [4].

Utilization of the energy obtained from the solar panel system in greenhouse soil disinfection is possible with converting such energy to thermal energy. Resistance wires laid in the soil must be used for this purpose. Such wires shall not generate temperatures higher than 85-90^{o}C. High temperatures cause not only the harmful soil bacteria but also the useful soil bacteria to lose their vitality. Rheostat or dimmer must be added to the system in order to adjust the temperature in case the resistance wires generate higher temperatures. These soil temperatures should be measured and recorded with various thermometers.

2.3. Solar Panel Utilization in Greenhouse Soil Disinfection

Utilization of electrical energy generated by solar panels in greenhouse soil disinfection is possible by converting such energy to thermal energy. Thermal energy derived from such procedure shall not exceed 80-90^{o}C. The reason is beneficial bacteria in the soil are capable of maintaining their vitalities up to such temperatures.

Resistance wires or heating bands are used in the system in order to generate thermal energy from electrical energy [9]. Such resistance wires must be soil- and water-resistant in order to be utilized in the greenhouses. Energy consumption of resistance wires produced for such purpose is 25 W m^{-1}or the heating bands have an energy consumption of 17-18 W m^{-1}. Occasionally it may be necessary to utilize the resistance wires at temperatures below 80-90^{o}C. Soil heating may be required to boost root activities of the plants cultivated in the greenhouses especially in colder seasons and promote their rapid growth. Increased water and nutrient intake through plant roots ensures increased efficiency as well [20]. Rheostat or dimmer must be added to the system in order to adjust the electrical current intensity and lower the temperature in such cases.

Soil disinfection is more effective and completed in a shorter time with solar panel system in greenhouses where solarization is applied. The reason is that it is possible to achieve higher temperatures with such system. It is stated that greenhouse soil disinfection must be applied for minimum 4 weeks with solarization [19]. Temperature varies between 45-55^{o}C up to 10 cm soil depth with solarization [25]. Main target is to increase the soil temperature which decreases the efficiency of diseased factors, nematode and microorganisms in the soil. It is possible to increase the greenhouse soil temperature to approximately 80-90^{o}C using resistance wires with solar panels. This might ensure that soil disinfection is completed one week earlier.

3. Conclusions

Electrical energy generated by solar panel system may be utilized in greenhouses in various manners at various times.

Solar panels to be installed and the electrical energy generated may be utilized for heating and disinfection

of greenhouse soils with solarization applied in summer. For this purpose, resistance wires or heating bands may be inserted to greenhouse soils in 25-50cm intervals at 10-15cm depths.

Power of the system installed with solar panels is approximately 4 kWh. However, as previously mentioned, it shall be possible to continuously utilize approximately 3 kWh of such power. Resistance wires with 25 W m^{-1} energy consumption are capable of heating 120 m section with 3 kWh. It is possible to disinfect an area approximately 60-120 m^2 by laying such wires in the greenhouse soil in 25-50 cm intervals. It may be possible to disinfect a wider area by frequently relocating the resistance wires used in the greenhouse soil.

It is possible to disinfect the soil in a very short time with solarization.

It is possible to heat the plant's root area in the production seasons of fall, winter and spring. Dimmer must be added to the system for such purpose. Lower temperatures can be achieved by decreasing the amount of energy supplied to the resistance wires using the dimmer. It is possible to heat a wider area by increasing the length of resistance wire to be utilized. Thus, the amount of water and nutrient intake by the plant is increased by improved plant root activity, and plant efficiency is also increased.

It is possible to utilize the energy generated by the solar panel system for the ventilation required in the greenhouses during the production period. It is also possible to cool the greenhouses with fans and pads utilized with required ventilation.

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