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A new approach to soil solarization: Addition of biochar to the effect of soil temperature and quality and yield parameters of lettuce *(Lactuca Sativa L. Duna)*

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ABSTRACT

Soil solarization is a non-chemical method used to destroy soil borne pathogenic, harmful, and weed seeds in agricultural field and greenhouses. Solarization is generally applied in regions with high summer air temperatures and high solar radiation. Organic materials obtained as a result of the pyrolysis process in an anaerobic environment is called biochar. It can be produced from a wide range of plant and animal origin biomass sources. Lettuce plants are an important vegetable species grown after the application of solarization because of their high value and compatibility with autumn growing. Researchers reported that lettuce yields increased following soil solarization.

The aims of this work were to examine different mulch materials and addition of biochar (a new approach in soil solarization) of soil temperature change, and determine which month is more effective according to temperature difference, and also effect of solarization application on yield, quality, and leaf nutrient content characteristics of lettuce plant. The experimental site was located at the University of Suleyman Demirel University in Isparta and the study was conducted during summer and autumn of 2016. Two different polyethylene (PE) mulch materials have been tested. Four different treatments and non-solarization were performed in this research. There were PE mulch, bubble PE mulch, PE + biochar, bubble PE+ biochar and non-solarization treatments. In the parcels where biochar application is used, it was applied 150 g m^{-2} of the soil surface as a thin mulch.

Biochar added bubble solarization mulching film was determined to be more effective with regard to temperature increase and heat conservation in comparison with the traditional mulch material. Solar radiation played an important role in rising soil temperature with mulch material. With the fall of solar radiation in August, temperatures under mulching films decreased. But, temperature inside the greenhouse and the temperature of the bare soil did not change or it was affected less. Yield increase of 100% was attained for lettuce yield increase with biochar added bubble solarization mulch in comparison with the control. Thus, the study reached the determined objective and it has been determined that biochar use plays an important role in the effectiveness of solarization applications.

1. Introduction

Soil solarization is a non-chemical method used to destroy soil borne pathogenic, harmful, and weed seeds in agricultural field and greenhouses. In summer months, when no cultivation is done, application is carried out by mulching the moist soil surface with thin uncolored polyethylene (PE) mulching material for 4–6 weeks. Solarization is generally applied in regions—Mediterranean, desert, and tropical climates—with high summer air temperatures and high solar radiation (Stapleton, 2000). The widespread use of PE in agricultural applications depends on ease of processing, chemical resistance, high strength, and flexibility (Clarke, 1987; Katan and DeVay, 1991). It is critical that very thin uncolored PE mulch be used to trap solar heat because it allows passage to short wavelength solar radiation but doesn't transmit longer-wavelength radiation from the ground back into the atmosphere. It is converted into longer wavelength to infrared energy, creating a greenhouse effect (Stapleton, 2000; Marquez and Wang, 2014). Its application is simple and non-chemical; it catches the light energy of the sun and causes physical and biological changes in the soil. Many living harmful organisms in the soil are affected by temperatures higher than 39–40 °C in heating the soil (Stapleton and DeVay, 1995). Many researchers have tested PE mulch materials at

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Table 1
Weather data of research area (Jul–Aug).

Month	Mean of Outside Max Temp. (°C)	Mean of Outside Min Temp. (°C)	Mean of Inside Greenhouse Max Temp. (°C)	Mean of Inside Greenhouse Min Temp. (°C)	Mean of Outside Max Relative Humidity (%)	Mean of Outside Min Relative Humidity (%)	Mean of Inside Greenhouse Max Relative Humidity (%)	Mean of Inside Greenhouse Min Relative Humidity (%)	Mean of Total Sunshine Duration (h:m) Per Day
July	32.3	17.5	56.8	16	70	22	84.6	29.7	11.70
August	31.9	16.8	54.6	16	81.3	25.1	88.2	36.5	11.13

different thicknesses to increase the efficiency of solarization. Researchers have reported that thinner mulch materials show more effective solarization success (Barakat, 1990; Mudalagiriyappa et al., 1999; Stapleton, 2000; Candido et al., 2011; Cascone et al., 2012). D'Emilio (2017a) stated that totally impermeable films (TIF) and virtually impermeable films (VIF) have better spectroradiometric properties and higher temperatures than low density polyethylene (LDPE)

Black and other colored plastics are not suitable for solarization process because instead of allowing radiation and heating the underlying soil, solar energy is absorbed and diffused back into the atmosphere. Campiglia et al. (2000) provided 4–8 °C higher temperature values for uncolored PE mulch compared with a black PE mulch. Chase et al. (1999) stated that the uncolored PE material is more effective at increasing the temperature at different soil depths than the black one. Researchers have indicated that the most suitable material for solarization applications is uncolored plastic material (Mudalagiriyappa et al., 1999; Stapleton, 2000; Komariah et al., 2011; Granados et al., 2012).

Biofumigation is based on the incorporation of fresh plant mass or wet animal manure into the soil and mulching the soil surface with uncolored plastic film. However, Oz et al. (2017) reported that there was no significant increase on soil temperature compared with the solarization process. Despite the disadvantage of using black mulch material in soil solarization, a new approach to solarization is the addition of biochar: the use of light permeability properties of uncolored mulch material with the advantage that black material absorbs light and increases its own heat. The high carbon and mineral content of the organic materials obtained as a result of the pyrolysis process in an anaerobic environment is called biochar. It can be produced from a wide range of plant and animal origin biomass sources (e.g., woods, agricultural wastes). Biochar which is black, is a mixture of char and ash with the major part (70–95%) carbon (Upadhyay et al., 2014). Biochar addition affects the growth and health of the crop by changing the physical, chemical, and biological properties of the soil (Gasco et al., 2016; De Tender et al., 2016). Biochar addition to soil can lead to increased soil water permeability (Asai et al., 2009; Laird et al., 2010; Solaiman and Anawar, 2015) increased in soil pH (Chan et al., 2007) improve crop growth and yield (Lehmann et al., 2003). However, some researchers have reported that the biological effect of the biochar added to the soil for plant development is neutral or even negative (Spokas et al., 2012; Guerena et al., 2013; Mukherjee and Lal, 2014; De Tender et al., 2016).

Soil-borne plant pathogens, plant parasitic nematodes, and weeds are significantly reducing quality and yield in vegetable production (Butler et al., 2014). Lettuce plants are an important vegetable species grown after the application of solarization because of their high value and compatibility with autumn growing. Researchers reported that lettuce yields increased following soil solarization (Hasing et al., 2004; Candido et al., 2011; Pane et al., 2012).

The main aims of this work were to (i) examine different mulch materials and addition of biochar (a new approach in soil solarization) of soil temperature change, (ii) determination of amounts of solar radiation reaching the soil surface under different mulch materials, (iii) determine which month is more effective according to temperature difference, and also (iv) effect of solarization application on yield, quality, and leaf nutrient content characteristics of lettuce plant.

2. Material and method

2.1. Study site

The experimental site was located at the University of Suleyman Demirel University in Isparta and the study was conducted during summer and autumn of 2016 (July-August). The study is carried out under greenhouse condition. The research area is located between the coordinates 37° 50′ N and 30° 32′ E. The altitude is 1007 m. The greenhouse was 6 m wide, 20 m long with a base area of 120 m^2; built with bow roof, steel construction. The gutter height was 2.2 m and the ridge height was 3.4 m. The greenhouse was covered by a 200-μm-thick ultra violet (UV), infra red (IR), anti bacterial (AB), light diffuser (LD), anti fog (AF), ethylene vinyl acetate (EVA) additives film (Vatan Pls. Ltd) prior to soil solarization. The research area, where greenhouse was located, consists of medium and medium-fine textured, deep, salt-free soil with weak profile development. Measured soil textile was 46% clay, 35% silt and 19% sand. Measured soil pH was 7.72. The average organic matter content was 1.76%. Some weather data on the research area for July-August months were given in Table 1.

2.2. Experimental design

The solarization experiment was performed 2 × 2 m arranged in a randomized complete block design with three replications four different treatments and control parcel. The treatment was performed from 01 July to 31 August 2016. Two different polyethylene (PE) mulch materials have been tested. One of them was 0.03-mm thickness uncolored PE mulch material. It was applied commonly used by farmers. The other used was uncolored bubbled PE material with a diameter of 30 mm and height of 12.5 mm recommended by Bainbridge (2010) and Oz et al. (2017). Four different treatments and non-solarization were performed in this research. There were PE mulch (Sol), bubble PE mulch (BSol), PE + biochar (SolBC), bubble PE+ biochar (BSolBC), and non-solarization (NonSol) treatments. Prior to implementation of mulch materials, the soil was irrigated up to field capacity. The greenhouse ventilation was kept closed during the solarization treatment.

2.3. Soil temperature and solar radiation

Soil temperatures were measured in SolBC, BSolBC and NonSol treatments at depth of 2 cm and were measured in each treatment at a depth of 5 cm. All the measured temperatures were sampled every hour by a data logger (DS1925 The iButton® Maxim Integrated). Air temperature was constantly monitored outside and inside the greenhouse via HOBO data logger (U12-0006 Onset HOBO) (midpoint the greenhouse 1.5 m height above the floor). The global solar radiation ($W m^{-2}$) was measured using the wavelength range of 280–2800 nm pyranometers (PYR-P Apogee) inside and outside 1.5 m height the floor. Also, solar radiation values were measured during the application of the solarization on the soil surface in contact with the underside of each mulch material. The sensors were oriented north to south. All the variables measured were sampled every minute and averaged to hourly