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Effect of solarization under different applications on soil temperature variation and microbial activity

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Abstract

Soil solarization is an environment-friendly soil pasteurization technique which uses the solar energy to increase the soil temperature to diminish soil-related pests and pathogens. The efficiency of this technique is closely related with a number of factors such as soil water and organic matter contents and feature of cover material; therefore, the effect of solarization was studied under applications of CO_2, basaltic tuff (BT), organic matter (OM) and a different color plastic cover (PE2) on soil temperature and microbial activity as dehydrogenase enzyme activity (DHA) and soil respiration (CO_2). The trial was carried out in a greenhouse for 32 days. Organic matter, salt and lime contents, pH and texture class of greenhouse soil were 1.7%, 0.055%, 38.5%, 7.7 and clay, respectively. According to the results, while the lowest CO_2 value was determined as 12.9 mg/100 g ds. 24 h in the A6 (PE2) application, the highest CO_2 value was determined as 16.3 mg/100 g ds. 24 h in the A4 (+OM 1.5 kg/m^2) application. The dehydrogenase enzyme activities (DHA) yielded similar results with the applications, however, the highest value (291.2 µg TPF/10 g ds.) was in A7 (control). Soil (0-5 cm) temperatures varied between 28.1 and 60.1°C with applications and the lowest soil temperature was determined in the control plot. The effect of the applications to soil temperature led to significant differences statistically ($p<0.05$). The results documented that the organic matter (OM) and CO_2 amendments (OM or +OM+CO_2) had a role in protecting soil microbial activity (dehydrogenase-DHA) and soil respiration (CO_2) from the detrimental effects of the heating of solarization.

Key words: Soil solarization, soil microbial activity, organic matter.

Introduction

The enhanced food demands of the world after the 1950s due to the abrupt population increase caused the development of the over-consumption policies in agriculture and, thus, especially the intensive use of chemicals. Soils are exposed to chemical hazards due to this overuse creating negative effects on the agricultural practices, in need of the use of higher environmentally friendly techniques. Soil solarization is a hydro-thermal process, trapped in soil covered by a thin transparent plastic film, which uses the sunlight to raise the soil temperature sufficiently in controlling soil-borne pests and pathogens [1]. Currently, for the control of soil pathogens and pests soils are fumigated by some of the fumigation materials (methyl bromide) that are globally prohibited for their high toxicity and detrimental effects on the stratospheric ozone layer [1, 2]. Soil solarization is based on the exploitation of the solar energy for heating wet soil mulched with transparent PE sheets to 40-55ºC in the upper soil layer. Thermal killing is the major factor involved in the pest control process, but chemical and biological mechanisms are also involved [3].

Not only pests and pathogens were affected by all kinds of soil sterilization methods, but also beneficial soil microorganisms were negatively affected. The vast majority of soil microorganisms which are indispensable elements of the ecosystem, play significant roles in N, C, P and S cycles [4]. The soil solarization method is environmentally friendly and more ecologically safe than the other chemical applications. Synergistic effects of some organic materials applied with solarization have also been observed in some studies. Its high synergistic effect in its use in combination with various organic amendments against root-knot nematodes in greenhouse vegetable crops is more effective when compared to single treatments [5].

The effects of soil heating on nutrient dynamics and microbial populations depend on the temperature reached, its duration, and depth of heat penetration. The effects of biotic and abiotic stresses on soil organisms can be measured as changes in the biological activity, microbial biomass, soil respiration and activities of enzymes such as dehydrogenase [4]. According to the research of Scopa and Dumontet [6], solarization was effective in controlling the root-knot nematode damage, but, on the other hand it also affected the soil biota populations and their activities as a consequence of the repeated treatments. However, by the addition of organic matter to the soil, the negative effect of solarization on the microbial activity is reduced.

In this study, we investigated the effect of solarization under applications of CO_2, basaltic tuff (BT), organic matter (OM) and a different color plastic cover (PE2) on soil temperature and microbial activity.

Materials and Methods

The study was carried out under greenhouse conditions for 32 days, starting from 17th of July 2009. At the end of the trial, soil samples were collected for analysis of microbial activity, namely for CO_2 production and dehydrogenase activity (DHA). To determine the effects of solarization and applications on soil temperature, the daily surface soil (0-5 cm) temperature was recorded during the trial period (Fig. 1). The variants and the applications within the experiment are given below:

A1: +0.5 kg/m^2 CO_2 (dry ice or gas state) application
A2: +Basaltic tuff = 5 kg/m^2 (< 5 mm) application
A3: Different color and size cover material (UV+IR) application
A4: + Organic matter (OM) (1.5 kg/m^2) application
A5: +0.25 kg/m^2 CO_2 + 0.75 kg/m^2 OM application
A6: Normal solarization
A7: Control (no solarization and any other application)

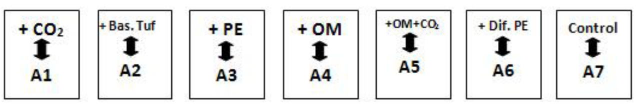

Figure 1. Applications (PE polythene, OM organic matter).

Basic soil properties of the study area: The experiment was carried out under greenhouse conditions at the Çukurova University, Faculty of Agriculture Farm. The soil properties of the study area are given in Table 1.

Analysis after trial: In order to determine the effects of solarization and the other OM applications on some biological properties, the dehydrogenase activity (DHA) [7] and CO_2 production [8] were measured after the trials. Variance analysis was performed on the data obtained from the study by the MSTAT-C software package (Department of Crop and Soil Sciences, Michigan State University, Version 1.2) and interpreted with Duncan's test according to Bek [9].

Experimental setup: The experiment was carried out from 17 July to 17 August 2009 at 2 m x 2 m plots that were prepared in the greenhouse with 3 replicates for 7 different applications. Solarization applied fields were plowed and seed-beds were prepared. The application materials were applied to the plots and a drip system was installed for irrigation. Each plot was covered by 100 μm PE materials - clean plastic sheets used for solarization and plastic cover edges were embedded in the soil to prevent heat and water loss of soil for a depth of 10 to 25 cm (Fig. 2).

Research area and climate: The study was carried out in a greenhouse located in Adana/Turkey (36°59' N, 35°18' E) at an elevation of 20 m above the sea level. The research area is under the influence of

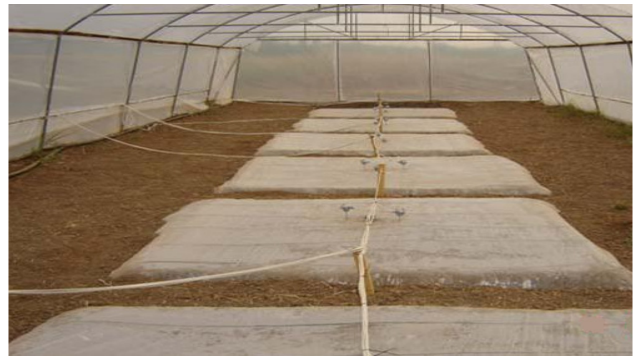

Figure 2. A view of the research plots.

the Mediterranean climate. The climate data for the research periods were taken on the climate monitoring station located in the University Farm. Meteorological stations were placed outside the greenhouse (Davis-Vantage Pro2 Plus) and air temperature was measured during the experiment. Soil temperature average values recorded daily and every 15 min are shown in Fig. 3.

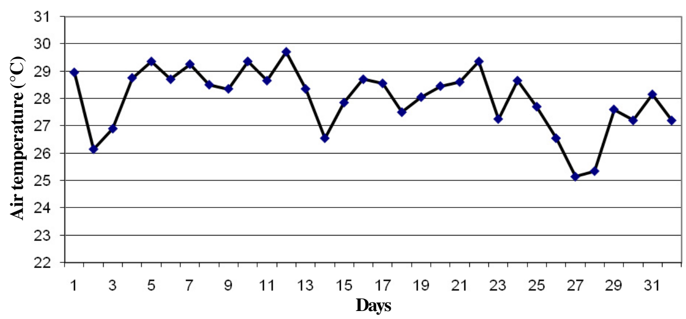

Figure 3. The mean daily air temperature outside the greenhouse during the experiment.

Results

The effect of solarization applications on soil temperature: The effects of solarization on daily maximum and minimum soil (5 cm) temperatures are given in Table 2 together with the greenhouse interior (So) temperatures. Table 2 illustrates the maximum and minimum daily temperatures ranging from 26.3 to 52.6°C and soil temperatures significantly affected by the applications ($p<0.05$). The average maximum soil temperatures ranged from 41.3°C (A7) to 51.2°C (A6) whereas the minimum values varied from 30.5 (A7) to 36.6°C (A2). The minimum and maximum average air temperatures were 22.1°C and 58.3°C in the greenhouse (So), respectively. The daily maximum and minimum average temperatures reveal the difference between the temperature of the control plots -35.9°C and the temperatures of the application plots varying from 42.3 to 43.7°C (Fig. 4), whereas, the average air temperature in the greenhouse (So) was 40.2°C.

The effect of the solarization on CO_2 production and dehydrogenase activity (DHA) in soil: The different greenhouse applications led to differences ($p<0.05$) in the CO_2 production (Table 3). The lowest value (12.9 mg/100 ds. 24 h) was found in the A6 (PE2) plots and the highest one (16.3 mg/100 ds. 24 h) in A4 (OM). The highest dehydrogenase activity (DHA) (291.2 mg TPF/ 10 g ds.) was measured in the A7 (control) plots. The dehydrogenase activity (DHA) values of the experiment were similar except those in the control plots (Table 4).

Table 1. Some features of the experiment area of soils.

Organic matter (%)	pH (1:1 H_2O)	Salt (%)	Lime (%)	Clay	Silt (%)	Sand	Texture class
1.7	7.7	0.055	38.5	44.2	36.7	19.1	C

Table 2. Effect of applications on soil temperature (ºC).

Date		A1	A2	A3	A4	A5	A6	A7	So*
17.07.2009	max	40.4	41.7	40.7	42.1	41.2	44.6	36.5	43.1
	min	30.1	29.4	26.9	30.6	31.3	30.4	28.4	22.8
18.07.2009	max	44.5	44.6	45.5	46.2	45.8	45.6	38.5	61.2
	min	28.9	28.6	28.2	28.5	28.8	28.7	26.3	20.3
19.07.2009	max	47.2	47.5	48.7	49.1	48.7	48.7	40.7	60.3
	min	32.0	32.8	32.1	32.4	32.6	32.4	28.1	22.4
20.07.2009	max	48.6	49.1	49.9	50.6	50.2	50.5	41.5	60.5
	min	33.8	34.5	34.2	34.6	34.5	34.2	29.7	15.8
21.07.2009	max	49.2	49.9	50.9	51.3	50.9	51.1	41.7	49.5
	min	35.3	35.9	35.6	35.6	35.5	35.4	30.1	26.1
22.07.2009	max	49.1	50.0	50.9	51.4	51.2	51.6	41.6	58.7
	min	35.8	36.6	36.1	36.3	36.2	36.2	30.9	24.5
23.07.2009	max	49.6	50.3	51.2	51.8	51.4	51.7	42.2	60.8
	min	35.8	36.7	36.2	36.5	36.3	36.3	30.9	23.4
24.07.2009	max	50.3	51.0	51.9	52.3	51.9	52.3	42.5	61.1
	min	36.4	37.2	36.8	36.9	36.8	36.6	31.5	24.8
25.07.2009	max	49.8	50.7	51.3	51.9	51.6	52.1	42.0	60.1
	min	36.4	37.3	36.9	36.8	36.6	36.8	31.4	22.5
26.07.2009	max	50.4	51.2	52.0	52.3	52.1	52.5	42.4	60.2
	min	36.6	37.7	37.0	37.2	37.1	37.1	31.7	23.6
27.07.2009	max	50.5	51.5	52.2	52.5	52.2	52.6	42.4	59.7
	min	36.8	37.8	37.2	37.3	37.3	37.2	31.8	23.1
28.07.2009	max	50.3	51.2	52.1	52.3	52.1	52.4	42.7	60.0
	min	37.1	38.0	37.2	37.5	37.2	37.2	31.9	23.7
29.07.2009	max	50.2	51.3	52.1	52.6	52.4	52.6	42.5	60.1
	min	36.4	37.4	36.7	36.9	37.0	36.8	31.6	20.6
30.07.2009	max	49.3	50.0	50.6	51.2	51.2	51.7	40.5	58.1
	min	35.6	36.5	35.9	35.8	36.1	35.8	29.2	20.0
31.07.2009	max	49.6	50.5	51.3	51.6	51.5	51.9	41.1	58.4
	min	36.8	37.8	37.2	37.3	37.4	37.1	30.1	22.7
01.08.2009	max	48.9	49.8	50.5	51.0	50.9	51.5	40.9	58.4
	min	36.9	38.0	37.3	37.5	37.5	37.3	30.3	23.6
02.08.2009	max	49.6	50.5	51.4	51.7	51.5	52.0	41.4	57.7
	min	36.7	37.8	37.2	37.1	37.1	37.2	30.5	23.1
03.08.2009	max	48.9	50.1	51.1	51.4	51.3	51.9	41.2	56.9
	min	36.4	37.5	37.1	37.0	37.0	37.0	30.4	21.6
04.08.2009	max	49.5	50.6	51.3	51.9	51.7	52.5	41.7	58.3
	min	36.1	37.3	36.7	36.5	36.8	36.8	30.4	20.6
05.08.2009	max	49.4	50.5	51.3	51.7	51.5	52.1	41.8	58.1
	min	36.2	37.5	36.8	37.0	37.0	36.9	30.8	22.0
06.08.2009	max	48.6	49.5	50.3	50.7	50.4	51.2	41.4	58.0
	min	36.9	38.2	37.7	37.8	37.5	37.8	31.8	23.5
07.08.2009	max	47.2	48.0	48.5	49.0	48.7	49.3	40.5	58.1
	min	37.1	38.3	37.7	38.0	37.8	37.9	32.2	25.6
08.08.2009	max	48.4	49.3	50.1	50.5	50.0	50.8	41.4	58.8
	min	36.0	37.1	36.5	36.7	36.4	36.6	31.2	22.5
09.08.2009	max	49.6	50.2	51.1	51.5	51.0	51.8	42.1	59.2
	min	36.5	37.7	37.2	37.2	37.0	37.1	31.7	24.1
10.08.2009	max	49.8	50.5	51.0	51.5	51.2	51.9	42.0	58.2
	min	36.5	37.6	37.1	37.2	37.0	37.1	31.7	22.2
11.08.2009	max	49.2	49.8	50.3	50.7	50.3	51.0	40.7	57.9
	min	35.2	36.2	35.7	35.6	35.7	35.7	29.6	18.6
12.08.2009	max	49.6	50.1	50.6	51.1	50.6	51.6	40.9	58.5
	min	35.3	36.4	35.8	35.9	35.7	35.8	28.9	16.9
13.08.2009	max	49.2	49.8	50.1	50.6	50.1	50.9	40.8	57.9
	min	35.4	36.4	35.8	35.8	35.7	35.8	29.0	18.1
14.08.2009	max	49.8	50.5	50.9	51.3	50.7	51.8	41.6	59.0
	min	36.5	37.4	36.7	36.9	36.6	36.9	30.4	21.8
15.08.2009	max	50.3	51.1	51.7	52.0	51.4	52.2	41.8	59.1
	min	36.8	37.7	37.0	37.0	36.9	37.1	30.8	21.2
16.08.2009	max	50.7	51.7	52.1	52.5	51.8	52.5	42.2	59.5
	min	37.5	38.5	37.9	38.0	37.7	38.0	31.6	23.2
17.08.2009	max	48.7	49.4	49.8	50.4	50.1	50.5	41.2	60.1
	min	37.7	38.8	38.0	38.1	37.8	38.1	31.9	22.8
The highest		50.7	51.7	52.1	52.5	52.4	52.6	42.7	61.2
The lowest		28.9	28.6	28.2	28.5	28.8	28.7	26.3	15.8
Max. mean		49.0 E	49.7 D	50.4 C	50.9 B	50.6 C	51.2 A	41.3 F	58.3
Min. mean		35.7 C	36.6 A	36.0 B	36.2 B	36.2 B	36.2 B	30.5 D	22.1

However, the lowest value (45.3 mg TPF/10 g ds) was found in the A6 plots and the highest value 51.9 mg TPF/10 g ds. in A4 (+ OM:1.5 kg/m^2 applications).

Discussion

Microbiological soil attributes readily change with different applications and are the indicators of soil productivity [10, 11] along with the nutrient cycling of N, P, C and S. Enzyme activities in soils can stand for the magnitude of soil biological productivity via their contributions to the metabolic reactions. The dehydrogenase enzyme is active within the microorganisms, thus yielding the nearest information on soil microbial activity at the time of sampling [12, 13]. One of the parameters used as a measure of biological activity of the soil is the CO_2 production in the soil (soil respiration). CO_2 is the end product of biological activity in soils in general and yields information on the magnitude of the decomposition of organic matter [10, 14]. However, soil moisture contents and the soil temperature are also important components in terms of microbial activities [15].

Our results revealed that soil was less adversely affected via the different applications of solarization concerning the addition of organic materials, similarly to earlier research [5, 6, 16]. The effects of CO_2 and DHA were similar to the effects of solarization on the soil properties. Consequently, solarization along with organic matter (OM) and OM+CO_2 amendment applications developed positive effects on microbial activity. Compared to the control plots the effect of A1, A2, A3 and A7 applications was insignificant on the production of CO_2, whereas all applications concerning DHA values were significantly lower than the control.

Scopa and Dumontet [6] have stated the side effects of solarization on soil microbial activity, and the similar effects of the pathogens enhanced by soil heating. Results have also revealed that the organic amendments (+OM, +CO_2) with solarization have a protective role on soil respiration (CO_2) and enzyme activities (DHA) against the detrimental effect of heating.

The vast majority of soil microorganisms are organotrophic, thus increasing biological activity in a variety of ways in each application with organic matter [17, 18]. This positive effect is very crucial to the

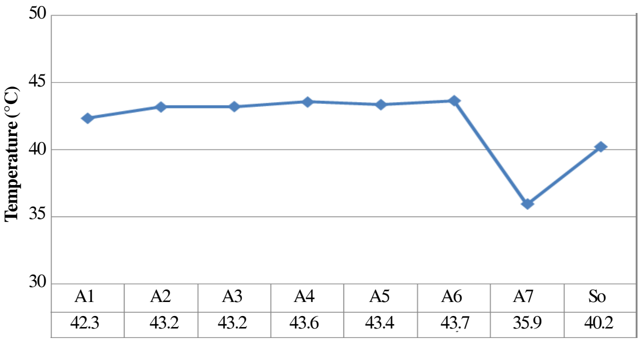

Figure 4. Effect of the applications on soil and air temperature of the greenhouse.

Table 3. Effect of applications on produce of CO_2.

Applications	mg CO_2/100g ds. 24 ha.	
A1	13.7	bc
A2	14.4	a-c
A3	14.5	a-c
A4	16.3	a
A5	16.0	ab
A6	12.9	c
A7	14.9	a-c
Ort.	14.7	

Table 4. Effect of applications on DHA activities.

Applications	DHA µg TPF/10g ds.	
A1	48.5	b
A2	49.4	b
A3	50.2	b
A4	51.9	b
A5	50.2	b
A6	45.3	b
A7	291.2	a
Ort.	84	

sustainability of microorganisms against the adverse soil conditions caused by solarized heating. As a consequence, the average maximum and minimum soil temperature measured was significantly higher than the control plots, in turn affecting the microbial activity in soil.

Conclusions

Considerably elevated soil temperature revealed by the application of solarisation, decreased the soil biological activity at a certain period. Supplementing of the organic material before solarization reduces undesirable circumstances as well as ensures soil beneficial biota to survive. Thus, when the solarization is an option, prior organic material application should take into consideration.

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