Scientific Papers. Series A. Agronomy, Vol. LX, 2017
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

AIR BUBBLED OR WATER FILLED BUBBLED SOLARIZATION SHEET WAS FURTHER EFFECTIVE ON NUMBER OF SOIL MICROORGANISMS, CO_2 PRODUCTION AS WELL AS MICROBIAL BIOMASS CARBON

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Abstract

Solarization has been commonly used method for last decades to eliminate weed and pathogen microorganisms which it is economic and environmental friendly. Despite of rising temperatures during soil solarization, some thermophilic or thermo-tolerant microorganisms may survive in the soil; therefore, natural soil flora re-establishes their activity soon after this practice. To evaluate the effects of different polyethylene cover materials as well as bio-fumigation applications, two years field experiments in 2011 and 2012 were carried out. In 2011, results revealed that heat-sensitive microorganisms in the surface soil have been eliminated rapidly. Sub soil layer was not as heated as the surface, thus, the higher CO_2 formation was determined in 15-30 cm soil depth. In the second year of experiment, heat-tolerant microorganisms become more dominant; therefore, the higher CO_2 production observed in surface than the sub soil. According to the enumeration carried out in 2011, the highest number of fungi at 0-15 cm soil depth was determined on the plots covered by water filled bubbled sheet. In 2012, the highest value was determined in a soil samples taken from 15-30 cm deep of conventional solarization application. Bacteria number was reduced up to soil depth; however, the highest bacteria number observed in air bubbled cover sheet treatment. There were great fluctuation on actinomycetes numbers, thus it is hard to evaluate the best cover material considering the data gathered. It was determined that the effect of temperature increase by solarization application on soil microorganism activity varies significantly between the years.

Key words*: actinomycetes, bacteria, fungi, microbial activity, solarization.*

INTRODUCTION

Soil solarization emerges as an environmentally friendly method of struggling to heat sensitive soil-borne pathogens by covering with soil polyethylene (PE) covering material for one or two months during the hottest months of the year. Herbicides are more preferred recently in conventional production systems because of the features such easy application and quick results. However, misuse of this xenobiotic chemicals lead to threatening of human and animal health, gaining resistance of the weed species to herbicides over time, damaging of non-targeted organisms etc. Solarization is the most important alternatives to chemical applications (Kitiş, 2011). Despite rising temperatures during soil solarization, some thermophilic or thermotolerant microorganisms in the soil can survive. These microorganisms colonize in the zone that occurs as a result of the death of pathogenic microorganisms. As a result of solarization the balance of pathogenic and beneficial organisms shift to a favor of beneficial organisms; therefore, long term effect occurs. Most of the microorganisms promoted after the solarization encourage biological control and plant development (Öztürk, 2008). Bio-fumigation not only stimulates the biological activity of the soil but also increases the soil organic matter content which helps to development of microorganisms. An effect of this practice is more apparent in the soils which have lower organic matter. As a result, bio-fumigation promote the plant development (Bello et al., 2008). Stapleton (1990) reported different temperatures for destroying plant pathogenic fungi, bacteria, weed seeds and nematodes; however, the elimination effect of the temperature of 45 °C or even higher, could not been evaluated. Furthermore, solarization is

effective on preventing colonization of competitive organisms in the soil. Although the heat generated in soil by solar radiation and the resultant death of plant pathogens and pests encompass the mayor principles of soil solarization, the increase in available plant nutrients and relative increase in populations of rhizosphere competent bacteria (Stapleton and DeVay, 1984). In this study, the effects of different PE cover material and bio-fumigation on soil microbial activity was studied.

MATERIALS AND METHODS

The research was carried out in 90 m^2 greenhouse at Suleyman Demirel University, Agricultural Research and Implementation Center for two years as 2011 and 2012. The texture class of the greenhouse soils was clay whereas organic matter contents and pH was 1.85% and 7.96, respectively. The water content of the soil at field capacity was 23.31% whereas the bulk density was 1.53 g cm^{-3}. Two different PE cover materials were used in the study. One was the 0.04 mm thick transparent PE covering sheet which used for solarization and bio-fumigation applications. This material commonly used by the farmers for regular solarization practices. Second was air bubbled PE sheet, which is available in the market as a packaging material. The diameter and the height of air bubbles were 30 mm and 12.5 mm. In this experiment this material was used either as is or bubbles were filled by water to gain condensing lens effect.

The experiment was consists of four experimental plots as well as control application. In the first application (Sol) a 0.04 mm thick colorless transparent PE covering sheet was used. Same sheet was used in second application (BioSol); however, before covering the soil 1.5 kg m^{-2} of fresh poultry manure was applied to the plot according to Barbour et al. (2002). In the third application (BSol), air bubbled packaging material was used as a solarization cover material in accordance with recommendation of Bainbridge (2010). The fourth application (BWSol) was the main tested idea in this experiment. The air bubbles of above mentioned material were filled with water in this application. The expected benefit from filling the bubbles with water is to focus the sun's rays and achieve a higher temperature in soil depth. The last application was the control (NonSol) which the soils were sampled between the test plots.

At the end of the solarization applications, 0-15 and 15-30 cm depth soils were sampled and their microbial biomass carbon (MBC), CO_2 formation as well as bacteria, fungi and actinomycetes numbers were determined according to Öhlinger (1993), Isermayer (1952) and Gürgün and Halkman (1988), respectively. Results statistically analyzed using MSTAT-C software (Crop and Soil Sciences Department, Michigan State University, Version 1.2) according to randomized complete block design.

RESULTS AND DISCUSSIONS

Microbial Biomass Carbon (MBC)

The amount of microbial biomass carbon, which is indicator of the total microbial abundance of soils, was determined by fumigation-extraction method and the obtained results are given in Table 1.

Table 1. Microbial biomass carbon values (µg C g dry $soil^{-1}$)

Years[1]	Depth	Sol	BSol	BWSol	BioSol	NonSol
2011	0-15 cm	25.35a	14.65abc	10.09c	17.82abc	17.06abc
	15-30 cm	8.23c	24.58ab	11.66bc	13.68abc	17.49abc
2012	0-15 cm	6.35d	47.88a	7.12d	23.57bc	17.93c
	15-30 cm	12.66cd	33.54b	22.22bc	20.65bcd	8.37d

[1]Different small letters indicate significant differences for P<0.05 in the column for each year

In the first year of the experiment, the highest MBC values were determined in the Sol application, whereas in the second year the highest value was obtained from the application of BSol. Considering these findings, both applications may be defined as the least

effective practices in suppressing total micro-organisms. On the other hand, the lowest values were determined at 0-15 cm depth of BWSol and 15-30 cm depth of Sol applications in the first year. In the second year, the lowest values were determined on the surface soils of Sol and BWSol applications whereas the highest were in BSol and BioSol. It can be said that the traditional solarization application is more effective in applications where low values are determined in terms of MBC values. Scopa et al. (2008) determined the microbial biomass carbon in their solarization studies and reported MBC as 34.69 µg C g dry soil^{-1}. The mean values obtained in the first year were lower than the values reported by Scopa et al. (2008) whereas the second year values were higher. This indicates that the heat sensitive organisms were disappeared in the first year and number of heat tolerant species is increased in the second year.

CO_2 formation of the soil

Although the numbers of microorganisms as well as MBC in the soil have been determined in the study, this may not represent the actual activity of soil microorganisms. Therefore, it was necessity to reveal the real activities of microorganisms (Çengel, 2004). Determining CO_2 as a respiratory product of the microorganism provides clear clue about the activity of the soil microorganism. Considering this fact, carbon dioxide production of experimental soil was determined and the obtained results are presented in Table 2.

Table 2. CO_2 production (µg CO_2 g dry soil^{-1} 24h^{-1})

Years[1]	Depth	Sol	BSol	BWSol	BioSol	NonSol
2011	0-15 cm	44.93a	45.43a	45.10a	47.47a	38.50b
	15-30 cm	50.13a	49.50a	48.27a	50.73a	43.40a
2012	0-15 cm	54.77a	59.27a	66.10a	63.77a	46.90b
	15-30 cm	55.10a	58.77a	55.37a	60.47a	47.50b

[1]Different small letters indicate significant differences for P<0.05 in the column for each year

Statistical differences ($p<0.05$) were determined between the values obtained for both years. Although it was not statistically significant, the higher values were obtained in the second year in correspondence with the MBC values (Table 1). The amounts of carbon dioxide formation measured in the deeper soil (15-30 cm depth) were higher than the surface soil (0-15 cm). Most probably this was because of the higher temperatures achieved at the surface as a result of solarization. However, in the second year the values in the surface soil were higher except Sol which kept its state. In the first year of solarization, heat sensitive microorganisms existing in the surface soil have been eliminated. As a result, higher CO_2 production was observed in the lower layers where temperature in this layer was not influenced as much as surface soil. In the second year of experiment, heat-tolerant microorganisms that were not as effected from first year application, become more dominant, thus, remaining ones promotes CO_2 production. Tülün (2011) carried out a solarization experiment and reported the highest and lowest CO_2 production as 20.75-11.32 mg CO_2 100 g_dry_soil^{-1} 24h^{-1}. In both years of the study where the results are given here, obtained values were considerably higher than these values.

However, the study of Tülün (2011) was carried out in the greenhouse where intense agricultural practices followed. Unlikely this study conducted on the greenhouse where no agricultural activities have been carried out for 3-4 years. Therefore, possible harmful inputs for soil microbiota such as fertilizers and agrochemicals were not widely used in this area. The higher values are seems to be associated with this situation.

Number of fungi, bacteria and actinomycetes

Solarization application increase soil temperature which threaten both harmful and beneficial microorganisms; however, at the end of solarization the beneficial organisms have

become predominant in a short time (Elmore et al., 1997). Classification progress was not followed in this research, yet, total fungal, bacterial and actinomycet numbers presented below in related subheadings without considering if they are beneficial or not.

Fungi enumeration

The number of fungi determined in the soil at the end of the solarization is given in Table 3. According to the enumeration in agar plate belonging to soils in 2011, the highest number of fungi was determined in 0-15 cm soil depth of BWSol application and in 2012 the highest value was determined 15-30 cm depth of Sol application. All values determined in the first year were lower than NonSol application whereas this phenomenon was not observed in the second year. Determination of fewer fungi in the second year can be explained by the residual effect of the first year solarization.

On the other hand, only Sol application provided higher fungi number in subsoil layer than surface. In the second year, the higher fungi numbers were determined in subsoil of Sol and BioSol applications. Based on the average results, it is thought that Sol application did not constitute sufficient effect in fungal elimination. In this application, it is estimated that the temperature increase in the first year does not spread enough to the depths, and fungi spores are transported to the upper layers at the second year. The increase on microorganism abundance in BioSol application can be explained by fresh poultry fertilizer application which is rich in microorganism.

Table 3. Fungi cfu numbers (*10^4 cfu g dry $soil^{-1}$)

Years[1]	Depth	Sol	BSol	BWSol	BioSol	NonSol
2011	0-15 cm	3.95de	8.16bc	15.08a	2.96de	8.30b
	15-30 cm	6.19cd	4.08de	11.31b	2.32e	9.15b
2012	0-15 cm	8.82b	4.03c	3.08c	3.18c	2.85c
	15-30 cm	12.72a	3.48c	2.44c	3.79c	4.13c

[1]Different small letters indicate significant differences for P<0.05 in the column for each year

Bacteria enumeration

Determined bacteria numbers at the end of the experiment were presented in Table 4. In the first year of the experiment, the highest bacteria number was in 0-15 cm soil depth of BSol application. Although bacteria number is decreasing by the depth, the higher value among the values belong to 15-30 cm depth was in BSol once more. In general, considerable lower bacteria numbers were determined in the second year, comparing to first year.

Table 4. Bacteria cfu numbers (*10^5 cfu g dry $soil^{-1}$)

Years[1]	Depth	Sol	BSol	BWSol	BioSol	NonSol
2011	0-15 cm	5.58d	27.95a	17.71b	18.81b	4.94d
	15-30 cm	1.78d	21.77b	12.83c	2.23d	8.80c
2012	0-15 cm	0.50b	0.99ab	1.01ab	1.61a	1.60a
	15-30 cm	0.51b	0.47b	0.84b	0.98ab	1.78a

[1]Different small letters indicate significant differences for P<0.05 in the column for each year

Although there is no significant difference between the years of NonSol application, all of the surface areas of other applications are significantly reduced. These effect also observed in 15-30 depth of all applications except BioSol.

Actinomycetes enumeration

Actinomycet numbers determined in the soil are given in Table 5. It is hard to conclude a trend of the effects of applications considering the number of actiomycetes. Because in some applications actinomycet numbers increased, while in some applications they decreased. In

the first year of the study, the highest actinomycet number was determined at 0-15 cm depth in BSol application. According to second year measurements, the highest value was determined in BioSol application at a depth of 15-30 cm. The only significant increase was in the depth of 15-30 cm of BioSol application which was associated with the organic fertilizer application in this treatment.

Table 5. Actinomycetes cfu numbers (*10^5 cfu g dry $soil^{-1}$)

Years[1]	Depth	Sol	BSol	BWSol	BioSol	NonSol
2011	0-15 cm	2.79b	4.83a	3.36ab	2.21b	2.12b
	15-30 cm	3.20ab	3.35ab	2.78b	3.14ab	1.92c
2012	0-15 cm	2.63c	6.52b	3.05c	2.46c	1.84d
	15-30 cm	3.75c	2.62c	2.47c	13.11a	1.29d

[1]Different small letters indicate significant differences for P<0.05 in the column for each year

CONCLUSIONS

It has been determined that the effect of temperature elevation due to solarization on soil microorganism activity shows a significant difference between the years. Based on the overall results, different cover materials have different effects on soil microorganism related parameters indicating that the new approaches should be applied to improve benefit of solarization. Moreover, when the solarization is over, it is considered that the possible differences in the activity of the microorganism may disappear. Therefore, in order to determine the reliable activity values belonging to soil microorganism, sample should be collected before solarization application is over.

ACKNOWLEDGEMENTS

This research work was carried out with the support of Suleyman Demirel University, Scientific Research Projects under project no: 2795-D-11

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