Improvement of Soil Solarization through a Hybrid System Simulating a Solar Hot Water Panel

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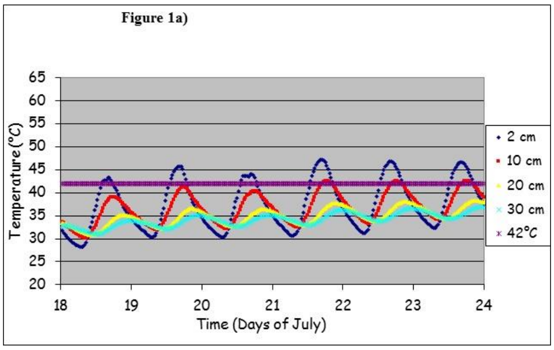
***Abstract*—Soil solarization is a well consolidated agronomic practice. The only limit of this natural practice is its duration, which normally reaches five-six weeks. Sometimes, because of the intensive cultivation, the available time between two vegetal cycles is shorter than that required for a good solarization result. In these cases, harmful alternative practices based on chemicals, like fumigation, are employed. In our work, we studied a new approach based on the combined use of a solarizing film and a biodegradable black liquid. The hybrid proposed system simulates a thermal solar panel and it behaves in the same way to increase the water temperatures in the soil. Therefore, higher soil temperatures are reached with a satisfactory sterilization effect obtained in shorter times, compared to the traditional method. The reported temperature data, collected at different depth of soil as a function of time, confirm the validity of our idea showing a helpful alternative respect to the present solarization method.**

Index *Terms*—solarization improvement, photoselective plastic films, biodegradable spray materials, new agronomical practice

I. INTRODUCTION

Soil solarization is a well known agronomical practice used to sterilize the soil by heating it through solar energy [1]-[9]. A good solarization is able to increase the soil temperatures at different depths up to eliminate the most part of pathogens accumulated during any crop cycle. This natural soil sterilization depends strongly on the temperature levels obtained, at different soil layers, during the solarization process. In other words, the higher are the temperatures the bigger is the solarization effect. The traditional solarization practice requires the use of a plastic film, with very good optical and thermal properties, covering the well wet field and a period long enough (4-5 weeks) in order to obtain a satisfying soil sterilization [4], [5]. Nevertheless, this not always is sufficient, mainly in some contests, where the times for solarization are very short and the sterilization results are poor or insufficient. Also the use of inadequate plastic film could frustrate a good soil sterilization, because the temperatures average levels during the whole period, are under the minimum threshold to eliminate very harmful pathogens, like *Nematodes*, that we estimated, according to the literature, about 42 ℃ [4], [5].



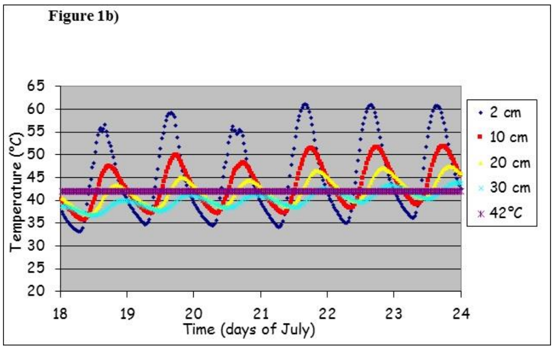


Figure 1. Comparison of experimental results obtained with two different plastic films. In Fig. 1a) the data exhibit an unsatisfying solarization, while in Fig. 1b) present temperatures more suitable for soil sterilization.

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In Fig. 1a) and Fig. 1b) we show a comparison between two solarization plastic films with different thermal and optical characteristics that affect the final results.

We plotted the temperature average level (42 ℃), under which the soil sterilization effect is insufficient. Fig. 1a) shows an unsatisfying situation, due to a shoddy plastic film, where most temperatures, at different depths, are under threshold, while Fig. 1b) exhibits a better situation, thanks to more appropriate optical and thermal properties of employed film for solarizing.

In the last decade, plastic films with innovative thermal and optical properties have been proposed aiming to improve furtherly soil solarization and, up to now, it seemed that this kind of practice had reached the state of maximum upgrade.

Nevertheless, a more appropriate sterilization, through solarization, requires still sufficiently long times (about one month) and highest temperature peaks up to 30cm depth in the soil. These conditions depend not only on the employed materials but also on weather that sometime is unfavorable, when the solarization practice is in progress. With the goal to give a further implementation to soil solarization, we studied an alternative method respect to the traditional one, based on the use of a very performing thermal film and a biodegradable black liquid, to spray on the soil in the final phase of irrigation and before covering with plastic film.

We are reporting on this methodological approach, on the employed materials and on experimental results presented in comparison with the traditional method of solarization.

II. Materials and Methods

In order to improve the traditional solarization the basic idea has been to reproduce a thermal solar panel in agronomical scale. A common solar hot water panel, see Fig. 2, is basically constituted of a black base (heat collector) and a thermal glass as cover, to optimize the "greenhouse effect" [10]. It means that the heat is completely trapped in the box, without energy loss (ideal case). In this situation the entering water (getting into the box) is heated and it can exceed 70 ℃. The water thermal gradients in these systems, which is the difference in temperature between in and out water, reach up to 40 ℃.

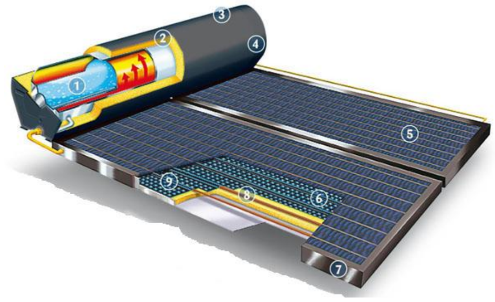

Figure 2. A schematic representation of a solar hot water panel.

In order to simulate the described system, we considered, as heat collector, an alginate based liquid, with dissolved carbon black powder, to spray on the soil at the end of irrigation that, according to the protocol for solarizing, is necessary for heat conduction, up to the internal layer of soil (30-40cm depth). Before covering with a solarization film, a very thin layer of liquid mixture, added to the irrigation water, is distributed on the soil. This material, after solidification, behaves like a solar collector which highly increases the temperature up to the most internal layer of the soil (30-40cm depth). For covering we selected two kinds of solarization plastic films, presented in the market and produced, in Israel and in Italy, respectively, both with thermal and optical characteristics necessary for using as solarization cover. We analyzed both films investigating their optical spectra, before the use for our experiment under greenhouse.

In particular, we focused our attention on the film that appeared more promising owing to their optical properties. According to the spectra that we performed of each sample, the film produced in Israel exhibits the transmittivity vs wavelength (see Fig. 3) that is extremely appealing for soil solarization.

As shown in Fig. 3A and Fig. 3B, the Transmittivity is very high in the range of solar radiation while the "holes", which correspond to heat emittivity of soil, guarantee a considerable block of IR radiation (heat energy) emitted from soil.

This property, in theory, induces a heat accumulation in the soil that turns in an increasing of temperature at different depths. In this paper we will label this thermal film, with strong peculiarities for solarization, **G** and the traditional film, with lower optical and thermal properties, **T**.

In order to simulate the same conditions existing in a thermal solar panel, we used a black liquid to spray on the soil after the normal irrigation. This operation creates a thin black film covering soil that behaves like a solar collector used to increase drastically the soil surface.

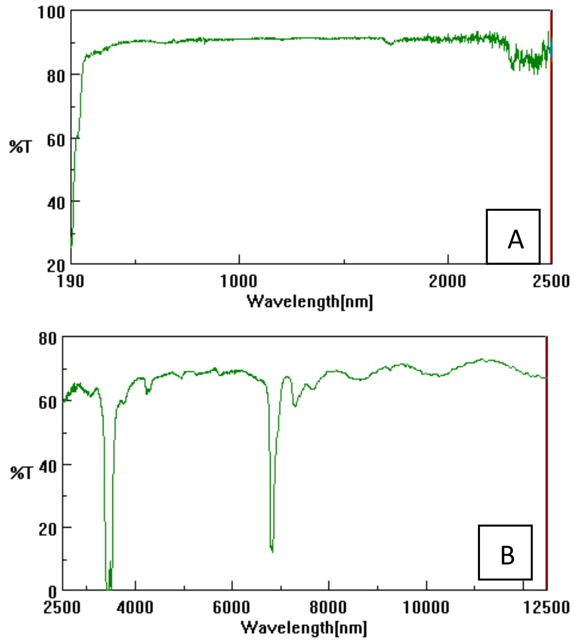

Figure 3. Optical spectra of more performing selected film in UV-Vis-NIR region (A) and IR region (B). The total transparency at solar radiation associated with two absorption peaks in IR region indicate ideal characteristics for solarization.

The solarization film, covering the soil, allows to confine the heat accumulation in the soil and, as a consequence, to increase the temperatures.

The black liquid was constituted of alginate based material with a low percentage of carbon powder giving the black color. We employed carbon powder to simulate a solar collector but, according to many papers published in literature reporting the positive contribute of such a material in agriculture [7], [8], it is obtained also an improvement in soil quality. In order to compare different types of black biodegradable liquids, even employed as solar collector, we studied three materials, for trials to be performed, as briefly presented in the following:

1) In 40 liters of tap water, we dissolve 100gr of sodium alginate. After dissolution at room temperature, we add 300 gr of glycerol and 200gr of lignin. This sample is named **AL1**. In 60lt of tap water we dissolve 100gr of sodium alginate. After dissolution at room temperature, we add 300gr of glycerol and 200gr of lignin and 100g of cellulosic fibers. This sample is named **AL**.

2) In 40 liters of tap water, we add 600ml of acetic acid, 100gr of chitosan, 300gr of glycerol and 300gr of lignin and natural black pigment. This sample is named **CH1**. In 60lt of tap water, we add 600ml of acetic acid, 100gr of chitosan, 300gr of glycerol, 300gr of lignin and 100gr of cellulosic fibers and natural black pigment. This sample is named **CH2**.

3) We prepare 40 liters of acetic acid solution 3% vol/vol, with 300g of lignin, 300g glycerol and black natural pigments. This sample is named **AA**.

III. The Experiment

In order to validate our new method, we performed three different trials, under greenhouse, lasting 30 days each (June, July and September), in the *Ristallo farm*, located at South of Naples (Italy): 40°31'27"N; 14°57'51"E.

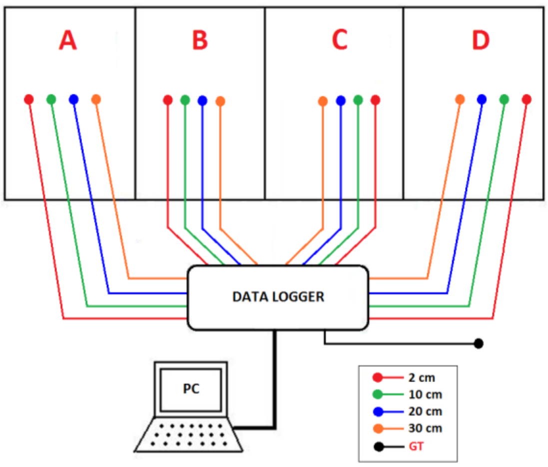

Figure 4. Scheme of the experimental setup. A-D: four parcels with thermocouple fixed at four depths. GT: Greenhouse temperature.

The experimental setup, schematically represented in Fig. 4, was constituted of four 2m×3m parcels, as described in the following Table I.

TABLE I. Design of Parcels for Trial in June 2014

Parcel A:	**A1** material and **G** plastic film
Parcel B:	**A2** material and **G** plastic film
Parcel C:	**G** plastic film
Parcel D:	**T** plastic film

The scheme was adopted for trials in June. For trials in July and September, in the same configuration, we tested as spray material CH1, CH2 and AA respectively, in parcel A and B, with the same plastic films.

The system for monitoring the temperature at different depths, for each parcel (Fig. 4), was constituted of 17 thermocouples (four for each parcel and one for monitoring the temperature inside greenhouse) connected to a data-logger for the data acquisition with a rate of 5 minutes for each channel. The thermocouples were fixed at 2cm, 10cm, 20cm and 30cm depth in the soil, respectively, for each parcel.

The experimental results are reported in Fig. 5a-Fig. 5d for the first month (18-26 June 2014) of data acquisition, at the four different depths. Each graph shows the temperature collected at same depth for each parcel as a function of the time.

In Fig. 6 the most significant differences in temperature (ΔT) are shown at four depths, in order to verify the increasing of the temperature, mainly between the parcels A and C. The comparison between the traditional method for solarizing (use of plastic film) and the hybrid one (use of black liquid as solar collector and plastic film) indicates, as expected, satisfactory increasing of temperatures with the combined system.

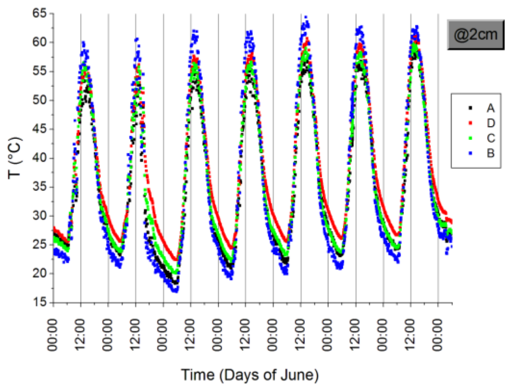

Figure 5a. Temperatures vs time at 2cm depth.

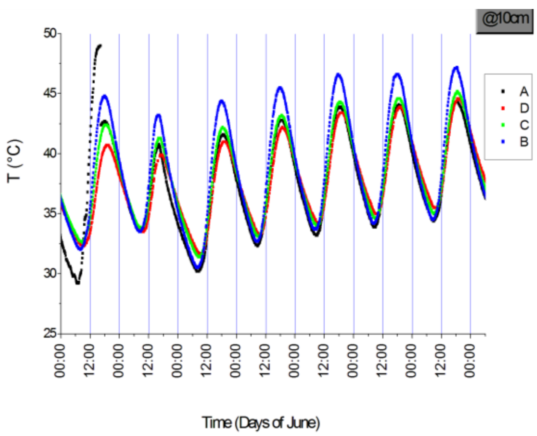

Figure 5b. Temperatures vs time at 10cm depth.

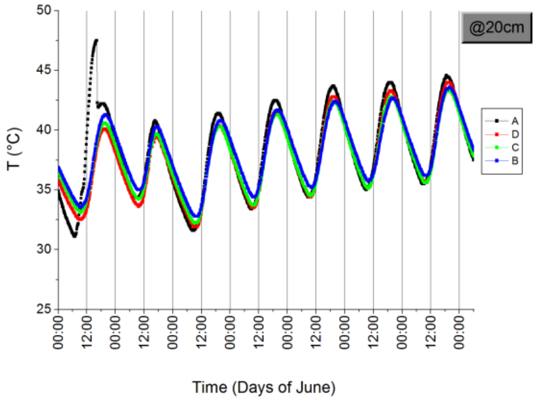

Figure 5c. Temperatures vs time at 20cm depth.

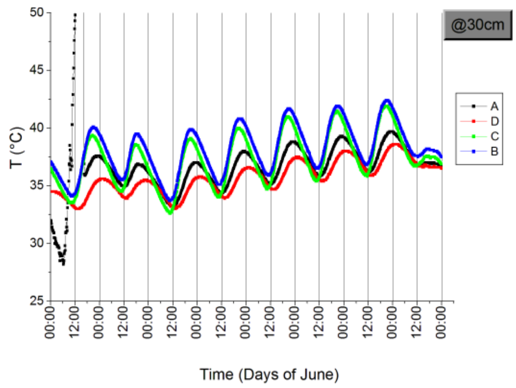

Figure 5d. Temperatures vs time at 30cm depth.

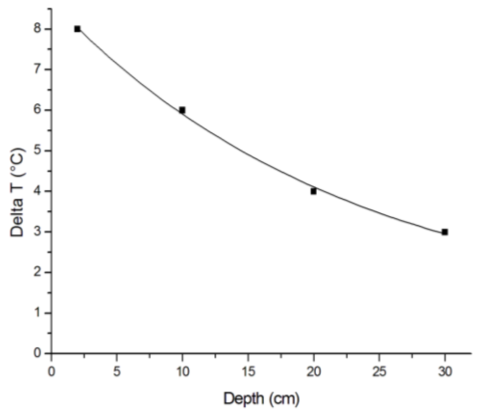

Figure 6. Increasing of temperature as a function of depths in the soil.

IV. Discussion

The idea to simulate a thermal solar panel, traditionally employed for producing home hot water just using solar energy, has been inspiring for the improvement of soil solarization practice. To this goal, we designed a hybrid system constituted of a thin black film (solar collector), sprayed on soil immediately after irrigation, and of a cover plastic film with high thermal properties.

In order to validate this innovative methodological approach, we performed three trials, lasting 30 days each, with a protocol studied to compare four different situation, as reported in Table I, measuring, as a function of time, the soil temperatures at different depths. The most important comparison was focused on the use of a solarizing film (traditional approach) and that one based on the hybrid system (innovative method). According to the experimental results the temperatures, collected at different depths (2cm, 10cm, 20cm and 30cm) in the soil, are higher with the combined system, with a ΔT ranging from 8℃ to 3℃. This considerable increasing of temperature confirm the expected results and, at the same time, indicate the efficiency of the new method. Our method, without altering the traditional practice of solarization, results positive also from an economical point of view, because the liquid black is a simple and very cheap material.

In conclusion, we believe that, according to our results, it will be possible to introduce the new solarization practice in order to obtain a better soil sterilization in shorter times, in comparison with the traditional method.

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