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# Integration between soil solarization and four biofungicides for controlling garlic white rot disease

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**Abstract**

**Impact of soil solarization and different biofungicides and/or Folicur fungicide as dipping treatment on the incidence of white rot and bulb yield of garlic was investigated. Results revealed that solarization treatment reduced percentage of white rot (WR) of garlic plants and increased garlic bulb yield compared to un-solarized infested soil under greenhouse and filed conditions. On the other hand, dipping garlic cloves before planting in four biofungicides *i.e.* Bio Arc, Bio Zeid, Bio Nagi and Bio-4 and/or Folicur fungicide significantly reduced WR disease incidence compared with untreated cloves. Dipping treatment with Folicur fungicide (tebuconazole) gave the highest reduction of WR % followed by the biofungicides *i.e.* Bio Nagi and Bio Zeid, respectively under greenhouse and field experiments during the two growing seasons (2015/16 and 2016/17), meanwhile, Bio-4 followed by Bio Arc resulted the least effective ones in this respect. Integration between solarization and dipping treatments increased the efficacy of WR reduction with high significant differences compared to un-solarized infested soil under greenhouse and filed conditions. Soil solarized plus Folicur fungicide followed by Bio Nagi and Bio Zeid, respectively were most superior integrated treatments for suppressive garlic white rot disease under greenhouse and filed conditions. Bio Nagi achieved closer results to Folicur fungicide for controlling WR incidence at the two successive seasons. However, the most superior integration treatment for increasing garlic yield was solarization treatment combined with each of Bio Nagi, Bio Zeid and Bio Arc, respectively. Population densities of total fungi, bacteria and actinomycetes in artificially infested soil were greatly reduced directly after solarization than before solarization. Solarization treatment alone or in combined with different dipping treatments were greatly decreased the total fungi, bacteria and actinomycetes population counts as compared with un-solarized infested soil one during the three timing intervals (30, 60 and 90 days after planting). The suppressive effect of solarization and dipping treatments was more effective in reducing soil microbial counts during the first 30 days of planting, then was decreased gradually from 60 to 90 days after planting. However, the total counts of bacteria and actinomycetes were slightly increased in solarized soil after 60 days then it rapidly increased at the 90 days interval.**

**Keywords:** garlic, white rot disease, bulb yield, solarization, biofungicides, soil microbial counts.

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## Introduction

Garlic (*Allium sativaum* L.) is an important vegetable crop which cultivated for fresh and dry consumption. Garlic has been used as a flavoring agent and a traditional medicine since antiquity, and is now cultivated worldwide including Egypt (Satyal, et al., 2017). Nowadays Egypt occupies the fourth country in the world for garlic production (Abou El-Magd et al., 2014) In Egyptian market, garlic is one of the most highest-value cash crops. Garlic has multifarious use in local consumption, food, processing and exportation. Value of this crop in Egypt, reaches about 2.889 million dollars, representing 0.14% of the total value of Egyptian agricultural exports in the period of 2007-2009 (Eleshmawiy et al., 2010). The annual cultivated area by garlic in Egypt was 12688.51 hectares (ha) (equal 31354 fed) in 2015/16 season this area produced around 272769 Megagrams (Mg) or tons (1 Megagram is exactly 1000 kilograms) as mentioned by the yearly book 2016 of Economics and Statistics of the Economic Affairs Sectors, Agriculture Ministry in Egypt. White rot disease caused by *Sclerotium cepivorum* is one of the major fungal diseases reducing yield of garlic throughout the world, including Egypt. White rot is a significant threat to garlic and onion in Egypt. The pathogen produces a great number of poppy seed-sized sclerotia, which can survive in soil for many years. Once the land has been infested, it is generally considered not suitable for garlic or onion production for up to 40 or more years (Bo Ming et al., 2010). The use of chemical fungicides is the most common control method for the disease at the present time. This control measure is costly, contaminates the environment, and harms non-target organisms (Mahdizadehnaraghi et al., 2015). Soil solarization is a method for soil disinfestation, implemented by increasing soil temperatures under transparent polyethylene sheets during the hot season. Early studies indicated that solarization may control *S. cepivorum* (white rot pathogen) in onions (Satour et al., 1989). In Egypt, *S. cepivorum* was completely controlled by solarization, even in heavily infested soils (Satour et al., 1989). Solarization was consistently found to reduce the viable inoculum density in the soil and provided good control of white rot of garlic in Spain and Mexico (Ulacio-Osorio et al., 2006; Melero-Vara et al., 2000). Biological control using microbial antagonists has been shown to be a suitable ecologically-friendly candidate who could replace chemical pesticides (Cook & Baker, 1988). Different fungal and bacterial antagonists have proved to be potential biocontrol agents for controlling many plant pathogenic fungi (Blaszczyk et al., 2014; Kakvan et al., 2013). Biocides or bioformulations of antagonistic fungi and bacteria can be used for controlling white rot pathogen,(*S. cepivorum*) in onion (Khalifa et al., 2013; Mohamed, 2012; Ouf et al., 2008) and garlic (Mahdizadehnaraghi et al., 2015). It has been reported that remediation of highly infested soils and sustainable management of Allium white rot not only be achieved by single treatment but also through a combination of strategies which might continuously several years (1 to 3, or more depending on the degree of soil infestation) before planting garlic or onion (Ulacio-Osorio et al., 2006). Therefore, the objective of this study was to evaluate the impact of combination of solarization, and different biofungicides on the incidence of white rot disease and the garlic yield, as well as soil microbial counts under artificially and naturally infestation in greenhouse and filed

conditions, respectively during the two growing seasons 2015/16 and 2016/17.

## Materials and methods

An experiment consisted of two main treatments namely, solarized (mulched with 35 µm VIF (virtually impermeable films) plastic and unmulched (exposed to direct sun-light) was conducted in artificially infested soil with *S. cepivorum* at greenhouse conditions at Agriculture Research Center, Giza and in natural soil heavily infested with *S. cepivorum* at field in Agricultural Research farm, El Khatatba location, Menofia governorate, Egypt.

**Greenhouse experiment:** Pot experiment was carried out in a randomized complete block design under greenhouse conditions at Agriculture Research Center, Giza.

**Preparation of fungal inoculum and soil infestation:** Reference isolate of Sclerotium cepivourum obtained from Onion, Garlic and Oil Crops Diseases Research Department, Plant Pathology Research Institute, Agriculture Research Centre, Giza, Egypt, for used in this study. Fungal inoculation of S. cepivorum was prepared using sorghum-coarse sand water (2:1:2 v/v) medium. The ingredients were mixed, bottled and autoclaved for one hour at 1.5 air pressure. The autoclaved media in glass bottles were inoculated separately using agar discs obtained from the periphery of five days old colony of the tested fungi and incubated at (20±2°C) for two weeks and used for soil infestation. Fungal propagules of S. cepivorum were added to the natural clay loam soil (around 200 kg soil) at the rate of 10.0 g/kg soil (w/w), mixed thoroughly with the soil. Infested soil was divided into two beds each one was (2.0 x 2.0 m2) in greenhouse then irrigated with water and left for one week for the inoculum establishment.

**Soil solarization:** Soil preparation that leads to a smooth soil surface facilitates plastic mulching and prevents tearing was done in this experiment. Infested soil with *S. cepivorum* in one of the two beds was thoroughly irrigated to reach field capacity in the upper 20 cm layer 1–2 days before being covered with 35 µm VIF (virtually impermeable films) plastic. Another bed was left without covering with 35 µm VIF plastic (exposed to direct sun light only). Soil solarization was accomplished by covering moist soil with VIF plastic on 15$^{th}$ July for 45 day. Covering soil with VIF plastic was provided every week with water for 30 min. through the drip irrigation system that located under the VIF plastic mulch to improve heat conduction for the more efficient eradication of the *S. cepivorum* in deeper soil (Satour et al., 1989). VIF plastic mulch was removed after 45 day.

**Biological treatments:** Four biofungicides, Bio Arc, Bio Zeid, Bio Nagi and Bio-4 as well as Folicur fungicide, were used in this investigation as dipping treatments and applied in combination with or without soil solarization for controlling garlic white rot disease. The two biofungicides Bio-Arc 6% WP and Bio-Zeid 25% WP are commercial biofungicides labeled on different crops in Egypt**.** However, the

other two biofungicides *i.e.* Bio Nagi and Bio-4 are still under registration and obtained from Identification of Microorganisms, Biological Control of Plant Diseases and Evaluation of Biofungicides Unit, Plant Path. Res. Inst., Agric. Res. Center, Giza, Egypt. Bio Arc is consist of (*Bacillus megaterium* $2.5x10^7$ cfu/g), Bio Zeid (*Tricoderma album* $10^7$ spore/g), Bio Nagi (*Tricoderma asperellum* $10^7$ spore/g) and Bio-4 (mixture of four *Bacillus* spp. *i.e. B. megaterium*, *B. subtilis*, *B. lechnifrmes* and *B. pumolis* $2.5x10^7$ cfu/g), as well as Folicur 25% EC fungicide (Tebuconazole).

**Biological and soil solarization treatments:** Plastic pots (30 cm-diam) were sterilized by dipped in 5.0% formalin solution for 15 minutes, left to dry for two days to get rid of formalin residues, then filled with infested soil (3kg/pot) previously solarized or unsolarized as mentioned before. The pots were containing either solarized or unsolarized infested soil were divided into equal two partitions and arranged in randomized complete block design with three replicates. Each partition was containing 18 pots (6 treatments x 3 replicates). Healthy garlic bulbs of Sids-40 cultivar (obtained from Onion, Garlic and Oil Crops Diseases Research Department, Plant Pathology Research Institute, Agriculture Research Centre, Giza, Egypt) were split into the individual cloves. The cloves were chosen for size homogenate and free from all defects and then soaked in water over-night. Apparently healthy garlic cloves were dipped in each particular biofungicide as mentioned above (5g/liter) and/or Folicur fungicide (25 ml/liter) mixed with 1% Arabic gum solution as sticker for 15 min. for biofungicide and 3 min. for fungicide, then raised and left to air dried before planting then planted at the first week of September 2015/162015/16 season in solarized or unsolarized infested potted soil at the rate of 5 cloves per pot. Three replicates (pots) for each particular treatment were used and garlic cloves were dipped before planting in 1% Arabic gum solution only as control. The number of garlic plants having specific white rot disease symptoms (yellowing, leaf dieback, and wilting) was counted after two and four month from planting and their percentage were calculated according to Hovius and Goldman (2004) as follows:

$$\text{Disease incidence (\%)} = \frac{\text{No. of garlic plants infected with white rot}}{\text{Total No. of garlic plants}} \times 100$$

Also, garlic plants from each pot of different treatments were collected after harvest and weighed as g/pot.

**Microbial populations:** Soil samples were collected at four different sampling periods with a sampling tube 2 cm inside diameter from the upper 10 cm of soil rhizosphere. Soil samples were taken pre and post solarization process in solarized or unsolarized infested soil as well as 30 and 60 days from planting. Three soil samples were collected from each treatment. The soil of each tube was bulked for each treatment and kept in plastic bags to form composite samples at 4°C to stabilize the microbiological activity distributed during soil sampling and handling according to the method of Johnson et al. (1959). For total microbial count determination at four different

sampling periods as mentioned above, plate count technique was applied using potato dextrose agar medium (PDA) and nutrient agar medium (Difco, 1985) to determinate total fungal and bacterial count, respectively. Total actinomycetes were estimated by the standard procedure of Rolf and Bakken (1987).

**Field experiment:** Field experiment was carried out during the two successive growing seasons 2015/16 and 2016/17 in natural soil heavily infested with *S. cepivorum* at Agricultural Research farm, El Khatatba location, Menofia governorate. The soil texture was sandy loam having the following characteristics, sand 60.5%, silt 24.2%, loam 15.5% and pH 7.6, EC 1. 36 ds/m, Organic matter 0.85% (Khalifa et al., 2017). The present study included 12 treatments (2 solarizaition treatments × 6 dipping treatments) that were laid out in a randomized complete block with three replicates. The two solarizaition treatments *i.e.* solarized soil treatment (mulched with 35 µm VIF plastic and unmulched soil treatment (exposed to direct sun-light). The size of the each plot was 10.5 $m^2$ (1/400fed.), each plot consisted of 6 rows, 50 cm wide and 3.5 m long. The soil was ploughed twice, listed to form raised beds and flood irrigated the day before VIF plastic sheets were placed on soil. Soil of plots to be solarized was thoroughly rotovated and irrigated to reach field capacity in the upper 30–40 cm layer 1–2 days before being covered with 35 µm VIF plastic. Soil solarization was accomplished by covering moist soil with 35 µm VIF plastic on 1st July 2015, and plots of the unmulched soil were left exposed to direct sun light. Edges of the VIF tarps were buried in furrows between beds. Special care was taken to minimize the distance between the tarps and soil to prevent the formation of air pockets that retard the soil heating process. All plots were supplemental irrigated with 10-15 cm flood irrigation every two weeks until the VIF plastic mulch were removed after 45day. Prior to planting, the field was irrigated (2-3 days) in order to provide good clove-soil- water contact. Healthy garlic bulbs were split into the individual cloves. The cloves were chosen for size homogenate and free from all defects, and then soaked in water over-night. Apparently healthy garlic cloves were dipped in each particular biofungicide and/or Folicur fungicide as previously mentioned in pot experiment and garlic cloves without any treatment were subjected as control. Cloves were planted at the first week of September in the two successive growing seasons 2015/16 and 2016/17 on both sides of each ridge at 10 cm apart in solarized or unsolarized infested plots. Fertilization and other culture practices were carried out as recommended. White rot incidence as a percentage of garlic bulbs with symptoms was assessed at harvest by pulling and observing all garlic bulbs in each plot. Also, garlic bulbs from each sub plot were harvested and weighed (kg/sub plot) for yield assessment.

**Statistical analysis:** The obtained data were statistically analyzed by analysis of variance (ANOVA) using MSTAT-C program version 2.10 (1991). Means were separation by Duncan test at $P < 0.05$ level.

## Results

**Integration between soil solarization and dipping treatments of garlic cloves on white rot incidence of garlic plants under artificially infested soil:** Data shown in Table (1) illustrate that, all treatments significantly decreased white rot disease incidence compared to untreated treatment (without any treatment). Solarization treatment led to reduced percentage infection of white rot (WR) of garlic plants with high significant differences compared to unsolarized infested soil. On the other hand, dipping garlic cloves before planting in four biofungicides *i.e.* Bio Arc, Bio Zeid, Bio Nagi and Bio-4 and/or Folicur fungicide caused significant reduction of WR disease infection in comparison with untreated cloves. Treated garlic cloves with Folicur fungicide was the best dipping treatment that cause the highest reduction of WR % followed by biofungicides *i.e.* Bio Nagi, Bio Zeid, and Bio Arc, respectively. Whereas treated garlic cloves with Bio-4 resulted the least one in this respect. Integration between solarization of infested soil and dipping treatments increased the efficacy of WR reduction with high significant differences compared to un-solarized infested soil. The superior treatments for controlling white rot disease under the artificially infested soil with *S. cepivorum* were soil solarized plus Folicur fungicide followed by soil solarized plus Bio Nagi and Bio Zeid, respectively. Bio Nagi achieved closer results to Folicur fungicide for controlling WR incidence.

Table 1: Effect of soil solarization combined with or without dipping treatment with some biofungicides and/or Folicur fungicide on disease incidence of white rot of garlic plants under pot experiment conditions.

| Dipping treatment | Garlic white rot incidence (%) | | | WR Reduction (%) | | |
|---|---|---|---|---|---|---|
| | Solarized soil | *Unsolarized soil | Mean | Solarized soil | *Unsolarized soil | Mean |
| Bio Arc | 26.7 | 40.0 | 33.4 | 49.91 | 50.00 | 49.96 |
| Bio Zeid | 20.0 | 33.3 | 26.7 | 62.48 | 58.38 | 60.43 |
| Bio Nagi | 13.3 | 26.7 | 20.0 | 75.05 | 66.63 | 70.84 |
| Bio-4 | 40.0 | 53.3 | 46.7 | 24.95 | 33.38 | 29.17 |
| Folicur fungicide | 6.7 | 13.3 | `10.0 | 87.43 | 83.38 | 85.41 |
| Control (untreated) | 53.3 | 80.0 | 66.7 | 0.00 | 0.00 | 0.00 |
| Mean | 26.7 | 41.1 | - | 49.97 | 48.63 | - |

*Un- Solarized soil *i.e.* exposed to direct sun-light only. LSD at 5% for: Soil solarization: (A) 0.59, - Dipping treatments: (B) 1.01, interactions (A x B): 1.43.

**Effect of combinations between soil solarization and garlic cloves dipping with some biofungicides and/or Folicur fungicide on yield of garlic plants under artificially infested soil in pot experiment:** Data presented in Table (2) show that all tested treatments caused significant increase in garlic yield (g/pot) compared to control. Garlic yield resulted from solarization treatment was higher than that resulted from un-solarized one. Also, dipping treatment in different biofungicides produce significant increase in garlic yield compared to untreated cloves. Bio Nagi, followed by Bio Zeid and Bio Arc, respectively were the best dipping treatments, meanwhile Bio 4 and Folicur fungicide were the least effective ones compared to control (without dipping treatment). The most

superior treatment that increased yield of garlic plants (g/pot) was soil solarization combined with each of Bio Nagi, Bio Zeid and Bio Arc, respectively, while dipping treatment only of Bio 4 and Folicur fungicide were the least effective treatments in this respect compared to control treatment.

Table 2: Effect of soil solarization combined with or without dipping treatment with some biofungicides and/or Folicur fungicide on weight of garlic plants as g/pot under pot experiment conditions.

| Dipping treatment | Weight of garlic plants (g/pot) | | Mean |
|---|---|---|---|
| | Solarized soil | *Un- Solarized soil | |
| Bio Arc | 210 | 165 | 187.5 |
| Bio Zeid | 250 | 190 | 220.0 |
| Bio Nagi | 290 | 220 | 255.0 |
| Bio-4 | 180 | 140 | 160.0 |
| Folicur fungicide | 160 | 135 | 147.5 |
| Control (untreated) | 110 | 50 | 80.0 |
| Mean | 200.0 | 150.0 | |

*Un-Solarized soil *i.e.* exposed to direct sun-light only. LSD at 5% for: Soil solarization: (A) 3.45, Dipping treatments: (B) 5.98, interactions (A x B): 8.46.

**Effect of solarization treatment on total count of fungi, bacteria and actinomycetes (colony forming unit) in garlic infested soil before and after solarization under pot experiment conditions:** According to the treatments that mentioned previously, results in Table (3) show the microbial populations (fungi, bacteria and actinomycetes count) in artificially infested soil with *S. cepivorum* treated by VIF plastic as a solarized treatment compared with un-solarized infested soil (exposed to direct sun light only) pre and post solarization treatment and before planting. All the microbial population counts in the infested soil were significantly affected by solarization treatment and the sampling time (pre- & post solarization) for determination total fungi, bacteria and actinomycetes. Solarization treatment caused significant reduction in fungal counts in comparison with untreated infested soil. On the other side, the decreasing of fungal counts was obviously detected at the end of experiment. Concerning of bacteria and actinomycetes counts, solarization treatment caused a slightly significant reduction in both bacteria and actinomycetes counts in comparison with untreated infested soil. Also, both bacteria and actinomycetes counts were differently affected slightly after solarization compared to before one. No significant differences was noticed neither total of fungi, bacteria nor actinomycetes counts taking pre solarization (zero time) whether in soil covered with VIF or left to sunlight.

Table 3: Effect of solarization treatment on total count of fungi, bacteria and actinomycetes (cfu) in garlic infested soil before and after solarization under pot experiment conditions

| Treatment | Total fungi, Bacteria and Actinomycetes counts at Pre & post Solarization | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fungi (CFU/$10^4$) | | | Bacteria CFU/$10^6$) | | | Actinomycetes(CFU/$10^4$) | | |
| | *Pre | **Post | Mean | Pre | Post | Mean | Pre | Post | Mean |
| Solarized soil | 39.09 | 4.52 | 21.81 | 5.93 | 5.14 | 5.54 | 1.76 | 1.62 | 1.69 |
| Un- solarized soil | 39.53 | 31.22 | 35.38 | 6.11 | 6.05 | 6.08 | 1.80 | 1.73 | 1.77 |
| Mean | 39.31 | 17.87 | - | 6.02 | 5.60 | - | 1.78 | 1.68 | - |
| LSD. 5% for: | | | | | | | | | |
| Soil solarization: (A) | | 1.684 | | | 0.111 | | | 0.050 | |
| Samples timing: (B) | | 1.710 | | | 0.034 | | | 0.042 | |
| A x B interactions | | 2.419 | | | 0.158 | | | 0.060 | |

*Pre solarization (Zero time) and **Post Solarization before planting

**Effect of soil solarization combined with some biofungicides and folicur fungicide as dipping treatment on total fungal count 30, 60 and 90 days after planting in infested soil under pot experiment conditions:** Data shown in Table (4) illustrated the effect of dipping treatment of garlic cloves in some biofungicides and folicure fungicide combined with or without soil solarization treatment on fungal population counts at 30, 60 and 90 days after planting in artificially infested soil with *S. cepivorum*. In general, all treatments caused significant decreased of fungal counts either 30, 60 or 90 days from planting in comparison with un-treated control. Solarization treatment caused a highly significant reduction in fungal counts in comparison with un-solarized one during all sampling time. The effect of solarization was decreased gradually from the first sample time to the last one. Regard for dipping treatments, all tested biofungicides and folicure fungicide significantly reduced the total fungal counts after 30, 60 and 90 days from planting and this reduction was gradually decreased from 30 days to 90 days. Folicure fungicide and Bio Nagi followed by Bio Zeid were the best ones in this respect during the experiment. Meanwhile, Bio Arc and Bio 4 were the least significant ones compared with un-dipping treatment. Concerning the interaction between soil solarization treatment and dipping treatments, the same results in Table (4) stated that integration between solarization treatment and the tested biofungicides and folicure fungicide was more effect in reducing fungal population counts than the individual treatment. Solarization treatment combined with dipping treatment *i.e.* Folicure fungicide or Bio Nagi followed by Bio Zeid were the best treatment in reducing the total fungal counts after 30, 60 and 90 days from planting. On the other hand, the total fungal population count was significantly affected directly after soil solarization and dipping treatments to 30 days whereas increased gradually from 60 to 90 days after planting in comparison with untreated control.

Table 4: Effect of soil solarization combined with or without dipping treatments with some biofungicides and/or Folicur fungicide on total count of fungi (CFU/$10^4$)in the garlic infested soil during different growth intervals after 30, 60 and 90 days of planting under pot experiment conditions.

| Dipping treatment | Total fungal counts (CFU/$10^4$) after 30, 60 and 90 days of planting in solarized and un-solarized infested soil | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 Days | | | 60 Days | | | 90 Days | | |
| | Solar. | *Un-Solar | Mean | Solar. | *Un-Solar. | Mean | Solar. | *Un-Solar. | Mean |
| Bio Arc | 6.73 | 25.15 | 15.94 | 12.82 | 28.57 | 20.70 | 18.93 | 31.89 | 25.41 |
| Bio Zeid | 5.12 | 19.80 | 12.46 | 9.54 | 21.35 | 15.45 | 13.67 | 23.74 | 18.71 |
| Bio Nagi | 4.09 | 15.32 | 9.71 | 6.27 | 18.91 | 12.59 | 9.68 | 21.53 | 15.61 |
| Bio-4 | 8.82 | 28.08 | 18.45 | 15.91 | 31.73 | 23.82 | 23.64 | 33.87 | 28.76 |
| Folicur | 3.64 | 13.92 | 8.78 | 5.83 | 15.17 | 10.50 | 8.29 | 18.83 | 13.56 |
| Control | 12.07 | 31.97 | 22.02 | 22.13 | 35.22 | 28.68 | 28.52 | 38.35 | 33.44 |
| Mean | 6.75 | 22.37 | - | 12.08 | 25.16 | - | 17.12 | 28.04 | - |

| LSD. 5% for | Total fungal (CFU/$10^4$) after 30, 60 and 90 days of planting | | |
|---|---|---|---|
| | 30 Days | 60 Days | 90 Days |
| Soil solarization: (A) | 1.925 | 0.351 | 0.419 |
| Dipping treatment:(B) | 3.334 | 0.608 | 0.725 |
| A x B interactions: | 4.715 | 0.859 | 1.025 |

* Un- Solarized soil *i.e.* exposed to direct sun-light only.

**Effect of soil solarization combined with some biofungicides and folicur fungicide as dipping treatment on total bacterial count 30, 60 and 90 days after planting in infested soil under pot experiment conditions:** Table (5) showed the effect of integrated treatment between dipping of garlic cloves in some biofungicides and folicure fungicide combined with or without soil solarization treatment on bacterial population counts 30, 60 and 90 days after planting in artificially infested soil with *S. cepivorum*. Generally, all tested dipping treatments caused significant increasing of bacterial counts 30, 60 or 90 days from planting in comparison with un-treated control in both solarized and un-solarized treatments. The total bacterial count was significantly decreased in solarized treatment in comparison with un-solarized during the three samples timing 30, 60 and 90 days after planting. Solarization decreased gradually bacterial populations from 30 days to 90 days from planting. Regard for dipping treatments, Bio Arc followed by Bio four were the best dipping treatments gave the highest population of bacterial counts during the three samples timing 30, 60 and 90 days after planting followed by Bio Nagi and Bio Zeid. Meanwhile, Folicure fungicide caused significant decreasing in total bacterial count and was more effect in reducing bacterial populations than un-dipping treatment in both solarized and un-solarized treatments. Integration between soil solarization and Folicure fungicide gave the highly reducing the total bacterial counts after 30, 60 and 90 days from planting. On the other side, the best integrated treatment for improvement increasing bacterial populations were un-solarized treatment (exposed to direct sun-light only) plus Bio Arc after 60 and 90 days followed by Bio four after 90 days from planting, respectively in comparison with untreated control and Folicure fungicide.

Table 5: Effect of soil solarization combined with or without dipping treatments with some biofungicides and/or Folicur fungicide on total count of bacterial (CFU/$10^6$) in the garlic infested rhizosphere soil during different growth intervals after 30, 60 and 90 days of planting under pot experiment conditions.

| Dipping treatment | Total bacterial counts (CFU/$10^6$) after 30, 60 and 90 days of planting in solarized and un- solarized infested soil | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 Days | | | 60 Days | | | 90 Days | | |
| | Solar. | *Un-Solar | Mean | Solar. | *Un-Solar. | Mean | Solar. | *Un-Solar. | Mean |
| Bio Arc | 15.39 | 21.23 | 18.31 | 17.88 | 34.17 | 26.03 | 23.15 | 37.68 | 30.42 |
| Bio Zeid | 12.65 | 16.48 | 14.57 | 14.07 | 19.26 | 16.67 | 16.52 | 23.17 | 19.85 |
| Bio Nagi | 13.49 | 17.30 | 15.40 | 15.86 | 20.91 | 18.39 | 16.12 | 22.06 | 19.09 |
| Bio-4 | 14.83 | 20.73 | 17.78 | 16.52 | 25.85 | 21.19 | 19.78 | 28.43 | 24.11 |
| Folicur | 6.73 | 7.18 | 6.96 | 7.81 | 8.95 | 8.38 | 9.07 | 10.19 | 9.63 |
| Control | 8.94 | 10.55 | 9.75 | 9.67 | 14.36 | 12.02 | 11.33 | 17.09 | 14.21 |
| Mean | 12.01 | 15.58 | - | 13.64 | 20.58 | - | 30.42 | 30.42 | - |

| LSD. 5% for | Total bacterial (CFU/$10^6$) after 30, 60 and 90 days of planting | | |
|---|---|---|---|
| | 30 Days | 60 Days | 90 Days |
| Soil solarization: (A) | 0.152 | 0.315 | 0.323 |
| Dipping treatment:(B) | 0.264 | 0.546 | 0.559 |
| A x B interactions: | 0.373 | 0.772 | 0.790 |

* Un- Solarized soil *i.e.* exposed to direct sun-light only.

**Effect of soil solarization combined with some biofungicides and folicur fungicide as dipping treatment on total actinomycetes count 30, 60 and 90 days after planting in infested soil under pot experiment conditions:** Table (6) clear the effect of soil solarization treatment that combined with dipping garlic cloves in some biofungicides and folicure fungicide in comparison with un-solarized soil and undipped control on actinomycetes population counts after 30, 60 and 90 days from planting in artificially infested soil with *S. cepivorum*. Solarization treatment caused significant reduction in actinomycetes count compared to un-solarized one during the three samples timing 30, 60 and 90 days after planting. All tested dipping treatments caused significant increasing of actinomycetes counts 30, 60 or 90 days from planting except dipping treatment in Folicure fungicide that caused significant decreasing in total actinomycetes more than un-dipping treatment in both solarized and un-solarized treatments. Bio Nagi and Bio Zeid were the best biofungicides during the three different growth intervals (30, 60 and 90 days of planting) which increased actinomycetes population. Meanwhile, Bio Arc and Bio four were the least significant ones in this respect compared with un-dipping treatment. The effect of solarization on actinomycetes populations was decreased gradually from 30 days to 90 days from planting. Integration between soil solarization and Folicure fungicide gave the highly reducing the total actinomycetes during the three sampling intervals. On the other side, individual dipping treatment of Bio Nagi followed by Bio Zeid after 90 days after planting, respectively gave the highest increasing of actinomycetes count.

Table 6: Effect of soil solarization combined with or without dipping treatments with some biofungicides and/or Folicur fungicide on total count of actinomycetes count (CFU/$10^4$) in the garlic infested rhizosphere soil during different growth intervals after 30, 60 and 90 days of planting under pot experiment conditions.

| Dipping treatment | Total actinomycetes count (CFU/$10^4$) after 30, 60 and 90 days of planting in solarized and unsolarized infested soil | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 Days | | | 60 Days | | | 90 Days | | |
| | Solar. | *Un-Solar. | Mean | Solar. | *Un-Solar. | Mean | Solar. | *Un-Solar. | Mean |
| Bio Arc | 1.76 | 2.39 | 2.08 | 1.92 | 3.14 | 2.53 | 2.34 | 4.08 | 3.21 |
| Bio Zeid | 2.13 | 2.58 | 2.36 | 2.71 | 2.97 | 2.84 | 3.54 | 3.81 | 3.68 |
| Bio Nagi | 2.61 | 2.75 | 2.68 | 2.99 | 3.21 | 3.10 | 3.40 | 4.34 | 3.87 |
| Bio-4 | 1.95 | 2.11 | 2.03 | 2.31 | 2.86 | 2.59 | 2.73 | 3.79 | 3.26 |
| Folicur | 1.18 | 1.27 | 1.23 | 1.62 | 1.85 | 1.74 | 1.93 | 2.26 | 2.10 |
| Control | 1.39 | 1.43 | 1.41 | 1.64 | 1.93 | 1.79 | 2.27 | 2.43 | 2.35 |
| Mean | 1.84 | 2.09 | - | 2.20 | 2.66 | - | 2.70 | 3.45 | - |

| LSD. 5% for | Total actinomycetes (CFU/$10^4$) after 30, 60 and 90 days of planting | | |
|---|---|---|---|
| | 30 Days | 60 Days | 90 Days |
| Soil solarization: (A) | 0.127 | 0.084 | 0.065 |
| Dipping treatment:(B) | 0.220 | 0.146 | 0.113 |
| A x B interactions: | 0.311 | 0.206 | 0.160 |

* Un-Solarized soil *i.e.* exposed to direct sun-light only.

**Effect of integration between soil solarization and garlic cloves dipping treatments on white rot disease incidence of garlic plants under field conditions during the two successive growing seasons 2015/16 and 2016/17:** Table (7) illustrate the combination between soil solarization of naturally infested soil with *S. cepivorum* and dipping treatment in some biofungicides and/or Folicur fungicide on percentage of garlic white rot incidence during the two successive growing seasons 2015/16 and 2016/17. All tested treatments significantly decreased white rot incidence compared to untreated treatment (without any treatment) in two successive growing seasons. Solarization treatment was highly effect in reducing white rot incidence of garlic plants with high significant differences compared to un-solarized naturally infested soil. On the other hand, dipping of garlic cloves before planting in the four tested biofungicides and/or Folicur fungicide caused highly significant reduction of WR disease incidence in comparison with untreated cloves. Dipping treatment with Folicur fungicide gave the highest significant reduction of WR % followed by Bio Nagi and Bio Zeid, respectively during the two growing seasons. Whereas treated garlic cloves with Bio-4 followed by Bio Arc resulted the least effective ones in this respect. Integration between solarization of naturally infested soil and dipping treatments increased the efficacy of WR reduction with high significant differences compared to un-solarized soil. The superior combination for controlling white rot disease under the naturally infested soil with *S. cepivorum* were soil solarized plus Folicur fungicide followed by soil solarized plus Bio Nagi and Bio Zeid, respectively during the two growing seasons 2015/16 and 2016/17. Bio Nagi achieved closer results to Folicur fungicide for controlling WR incidence at the two successive seasons.

Table 7: Effect of soil solarization combined with or without dipping treatment with some biofungicides and/or Folicur fungicide on disease incidence of white rot disease on garlic plants under field conditions during the two successive growing seasons 2015/16 and 2016/17.

| Season | Treatment | Garlic white rot disease incidence % | | Mean |
|---|---|---|---|---|
| | | Solarized soil | *Unsolarized soil | |
| 2015/16 | Bio Arc | 12.3 | 23.7 | 18.0 |
| | Bio Zeid | 7.9 | 16.4 | 12.2 |
| | Bio Nagi | 5.3 | 12.2 | 8.8 |
| | Bio-4 | 15.8 | 25.8 | 20.8 |
| | Folicur fungicide | 3.2 | 10.6 | 6.9 |
| | Control (untreated) | 27.6 | 35.4 | 31.5 |
| | Mean | 12.0 | 20.7 | - |
| 2016/17 | Bio Arc | 13.6 | 25.1 | 19.4 |
| | Bio Zeid | 9.2 | 18.3 | 13.8 |
| | Bio Nagi | 6.7 | 14.5 | 10.6 |
| | Bio-4 | 16.9 | 27.6 | 22.3 |
| | Folicur fungicide | 5.6 | 15.8 | 10.7 |
| | Control (untreated) | 30.4 | 41.7 | 36.1 |
| | Mean | 13.7 | 23.8 | - |

| LSD. 5% for | 2015/16 | 2016/17 |
|---|---|---|
| Soil solarization: (A) | 0.38 | 0.43 |
| Dipping treatment: (B) | 0.67 | 0.75 |
| A x B interactions | 0.94 | 1.06 |

* Un- Solarized soil *i.e.* exposed to direct sun-light only.

**Effect of integration between soil solarization and garlic cloves dipping treatments on garlic yield under field conditions during the two successive growing seasons 2015/16 and 2016/17:** Data presented in Table (8) illustrated that all tested treatments caused significant increase in garlic yield (Kg/plot (10.5 $m^2$)) compared to untreated control (without any treatment) during the two growing seasons 2015/16 and 2016/17. Solarization treatment was more efficacy for improvement garlic yield than un-solarized one (exposed to direct sun-light only). On the other hand, dipping treatment in different biofungicides produce a significant increase in garlic yield compared to untreated cloves. Bio Nagi, followed by Bio Zeid and Bio Arc, respectively were the best dipping treatments for increasing garlic yield, meanwhile Bio 4 and Folicur fungicide were the least effective ones in this respect in both growing seasons compared to control (without dipping treatment). The most superior integration treatment for increasing garlic yield was solarization treatment combined with each of Bio Nagi, Bio Zeid and Bio Arc, respectively, while dipping treatment only of Bio 4 and Folicur fungicide were the least effective treatments in this respect compared to control treatment during the two growing seasons 2015/16 and 2016/17.

Table 8: Effect of soil solarization combined with or without dipping treatment with some biofungicides and/or Folicur fungicide on garlic yield (Kg/plot) under field conditions during the two successive growing seasons 2015/16 and 2016/17.

| Season | Treatment | Garlic yield (Kg/plot 10.5 $m^2$) | | |
|---|---|---|---|---|
| | | Solarized soil | *Unsolarized soil | Mean |
| 2015/16 | Bio Arc | 19.4 | 15.7 | 17.6 |
| | Bio Zeid | 23.8 | 18.3 | 21.1 |
| | Bio Nagi | 25.6 | 20.6 | 23.1 |
| | Bio-4 | 17.7 | 15.4 | 16.6 |
| | Folicur fungicide | 18.1 | 16.9 | 17.5 |
| | Control (untreated) | 12.5 | 10.1 | 11.3 |
| | Mean | 19.5 | 16.2 | - |
| 2016/17 | Bio Arc | 18.6 | 14.3 | 16.5 |
| | Bio Zeid | 22.1 | 17.2 | 19.7 |
| | Bio Nagi | 24.2 | 18.6 | 21.4 |
| | Bio-4 | 16.3 | 14.8 | 15.6 |
| | Folicur fungicide | 17.9 | 15.7 | 16.8 |
| | Control (untreated) | 11.4 | 9.5 | 10.5 |
| | Mean | 18.4 | 15.0 | - |
| LSD. 5% for | | 2015/16 | | 2016/17 |
| Soil solarization: (A) | | 0.35 | | 0.34 |
| Dipping treatments: (B) | | 0.60 | | 0.58 |
| A x B interactions | | 0.85 | | 0.82 |

* Un- Solarized soil *i.e.* exposed to direct sun-light only.

## Discussion

During this investigation, the impact of combination between solarization and different biofungicides and/or Folicur fungicide on the incidence of white rot disease and the garlic yield was investigated under artificially and naturally infestation with *S. cepivorum* in greenhouse and filed conditions, respectively during the two successive growing seasons 2015/16 and 2016/17. Solarization treatment reduced percentage of white rot (WR) disease of garlic plants with significant differences compared to un-solarized infested soil under artificially and naturally infestation with *S. cepivorum*. These results in harmony with those obtained by Satour et al., (1989) who indicated that solarization may control *Sclerotium cepivorum* the causal pathogen of white rot disease in onions. In Egypt, *S. cepivorum* completely controlled was done by solarization, even in heavily infested soils (Satour et al., 1989). Several workers reported the success of solarization treatment in reducing plant diseases caused by soil-borne pathogens (Keinath, 1995). Long-term effects of soil solarization have been observed for control of pink root and white rot of onion (Abdel-Rahim et al., 1988). Soil solarization was the most effective treatment for eradicating *S. cepivorum* from infested soil in the pots and fields trials and years tested. Thus, the results obtained in previous studies on controlling garlic white rot in Spain (Basallote-Ureba & Melero-Vara, 1993) and elsewhere, on onion and garlic crops (Pereira et al., 1996) were confirmed. In previously field experiments in Egypt results indicated a more satisfactory

long-term effect of soil solarization to control onion WR despite furrow irrigation (Satour et al., 1989), which is determinant of inoculum spread from non-solarized to solarized plots. It has been reported that viability of *S. cepivorum* sclerotia is considerably reduced by exposure to temperatures above 30°C (Crowe & Hall, 1980) and exposures to 40°C for 39 h killed at least 50% of them (Adams, 1987). The increase in microbial processes induced by solarization could affect *S. cepivorum* by increasing its vulnerability to soil microorganisms (Katan, 1981). Dipping garlic cloves before planting in four biofungicides *i.e.* Bio Arc, Bio Zeid, Bio Nagi and Bio-4 and/or Folicur fungicide caused a high significant reduction of WR disease incidence in comparison with untreated cloves. These findings are in agreement with several researchers. Among them Ouf et al. (2008) studied the effect of three biofungicides, Rhizo-N, Plant Guard and Contans, against *S. cepivorum*. The antagonistic units of the biofungicides are *B. subtilis, T. harzianum* and *C. minitans*, respectively. They found that all biofungicides inhibited the growth of the pathogen. Mohamed (2012) found that using the biofungicides Bio Zeid, Bio Arc and Planta Guard under greenhouse condition decreased the percentage of disease incidence with rot and increased onion bulb yield. Khalifa et al. (2013) showed that fungal bioagents *i.e.* Bio Nagi and Bio Zeid were more effective than bacterial bioagents *i.e.* Bio Arc and Bio-4 for controlling white rot disease of onion. Mahdizadehnaraghi et al. (2015) indicated that bioformulations of antagonistic fungi including *Trichoderma harzianum, T. asperellum,* and *Talaromyces flavus* can be used for controlling garlic white rot which is one of the most important fungal diseases anywhere garlic is cultivated. The application of fungal and bacterial antagonists to the soil opens the possibility of disease control without the use of chemicals, and usually provides an environmentally sound control measure. Among the microorganisms reported to provide biocontrol of *S. cepivorum*, one of the most effective seemed to be *Trichoderma* spp. (Abd-El-Moity, 1992; Chet, 1987; De Oliveira et al., 1984). *Bacillus subtilis* (Ehrenberg) Cohn was also considered an effective biocontrol agent, inhibiting mycelial growth of *S. cepivorum* through antibiosis (Reddy et al., 1992). Reino et al. (2008) reported that *Trichoderma* spp. produce different secondary metabolites with antibiotic activity and have been classified in different groups based on their biosynthetic origin or their chemical structure, and they include non-volatile (*i.e.* peptaibols) and volatile compounds (e.g. simple aromatic metabolites, terpenes, the isocyano metabolites, some polyketides, butenolides and pyrones. Dipping treatment with Folicur fungicide (tebuconazole) gave the highest significant reduction of WR % under greenhouse and field experiments during the two successive growing seasons followed by biofungicides *i.e.* Bio Nagi and Bio Zeid, respectively. Whereas treated garlic cloves with Bio-4 followed by Bio Arc resulted the least effective ones in this respect. These results were in harmony with those obtained by Melero-Vara et al. (2000). They found that, treatment of garlic cloves with tebuconazole (at 1ml of Folicur 25%) achieved a significant reduction in the

rate of disease progress and the final incidence of plant death by *Sclerotium cepivorum.* In contrast, lower levels of disease control were obtained when selected isolates of *Trichoderma harzianum* and *Bacillus subtilis* were applied to the soil and cloves respectively. Tebuconazole was very effective for controlling garlic white rot disease when applied to the soil or with the garlic cloves (Felaifel et al., 2005; Jackson et al., 1997) but it was highly phytotoxic, causing seed and seedling mortality when used as a seed treatment for onion (Fullerton et al., 1995). The combined treatment between bioagents and fungicide or any other treatments may be useful to increase the efficacy of garlic or onion white rot disease control (Bandyopadhyayl & Cardwel 2003). The integration of the two most efficient methods of control of WR of garlic, *i.e.* soil solarization and Folicur (tebuconazole) treatment of garlic cloves, is suggested as very satisfactory method under high disease levels. This is of particular interest when a long-term effect of solarization is desired, since clove treatment with tebuconazole would be appropriate under low disease pressure such as in the second year after soil solarization. Integration between solarization and dipping treatments increased the efficacy of WR reduction with high significant differences compared to un-solarized infested soil under greenhouse and filed conditions during the two growing seasons 2015/16 and 2016/17. The most superior combination treatments for controlling white rot disease of garlic under artificially and naturally infestation with *S. cepivorum* in greenhouse and filed conditions, in the two growing seasons were soil solarized plus Folicur fungicide followed by soil solarized plus Bio Nagi and Bio Zeid, respectively during the two growing seasons 2015/16 and 2016/17. Bio Nagi achieved closer results to Folicur fungicide for controlling WR incidence at the two successive seasons. Melero-Vara et al. (2000) found that the application of different methods using soil solarization, bioagents (*T. harzianum, B. subtilis*) and fungicide (tebuconazole) were effective on controlling garlic white rot (WR) and crop yields and on the quality of garlic bulbs (long-term effect) under field conditions in southern Spain and soil solarization provided the best control of garlic white rot, bringing soil populations of *S. cepivorum* to negligible levels and garlic yields were improved. Therefore, the use of these biological control agents seems to be more appropriate as one component of integrated control practices that combines either with chemical treatments or with soil solarization (Chet 1987). Pereira et al. (1996) indicated that *T. harzianum* applied to solarized plots improved control of *S. cepivorum* compared with the results achieved with the addition of *B. subtilis*, applied after soil solarization. Ulacio-Osorio et al. (2006) reported that soil solarization significantly reduced inoculum density (75%), viability (84%) and disease incidence (88%), and increased garlic yield by up to 152%, compared with non-solarized treatments. Abou-Zeid et al. (2011) indicated that using biofungicides (Bio Arc and Bio Zeid) combined with solarization treatment gave acceptable results for controlling the major soil borne diseases of tomato (fungal pathogens & root-knot nematodes) and gave the best increasing

of tomato yield. Abada et al. (2015) showed that using of the two bioagents *B.subtilis* and *P.flurescens*, compost and soil solarization resulted in significant reduction to the severity of strawberry Fusarium wilt with significant increase to the fruit yield compared with control treatment. In addition, the combination between any of the tested bioagents and soil solarization was more efficient in reducing disease severity and increasing fruit yield than when each of them was used alone. Moreover, the combination among the two bioagents + compost + soil solarization was the most efficient in this regard. Concerning to garlic yield under both greenhouse and filed conditions, during the two growing seasons 2015/16 and 2016/17, the obtained results declared that garlic bulb yield that resulted from solarization treatment was higher than from un-solarized one. Also, dipping treatment in different biofungicides produce significant increase in garlic yield compared to untreated cloves. Bio Nagi, followed by Bio Zeid and Bio Arc, respectively were the best dipping treatments, meanwhile Bio 4 and Folicur fungicide were the least effective ones compared to control (without dipping treatment). The most superior integration treatment for increasing garlic yield was solarization treatment combined with each of Bio Nagi, Bio Zeid and Bio Arc, respectively, while dipping treatment only of Bio 4 and Folicur fungicide were the least effective treatments in this respect compared to control treatment during the two growing seasons. Satour et al. (1989) revealed that soil solarization has a great potential for increasing onion yield in the Mediterranean region. Melero-Vara et al. (2000) reported that soil solarization was also highly effective and caused a significant improvement in yield and garlic quality. Our results in agreement with a previous study on soil solarization (Basallote-Ureba & Melero-Vara, 1993). The obtained data illustrated that, population densities of total fungi, bacteria and actinomycetes were greatly reduced directly after solarization in solarized soil compared to before solarization in both solarized and un-solarized soil (exposed to direct sun light). Kamaluddeen and Simon (2013) used soil solarization by covering transparent polythene in summer season comparing to control plots (without solarized) which were left exposed to direct sun light and counted total microflora population at pre, post soil solarization and after 30 days of soil amendment. They showed that soil microflora was greatly reduced in solarized soil as compared to unsolarized one. On the other hand, before solarization, total count of soil microflora (fungi, bacteria and actinomycetes) showed no significant difference between solarized and unsolarized soil. The obtained data in agreement with El-Shanawany et al. (2004) who found that, immediately before starting soil solarization (at zero time), total count number of genera, number of species and density levels of species of soil fungi did not show any significant difference between mulched, unmulched and shaded soils at 0-10 and 10-20 cm depths. This result indicating homogeneity of the native mycocommunity present in the tested field. The decreasing of fungal counts was obviously detected after finishing of solarization treatment. Meanwhile, total

bacteria and actinomycetes counts, was slightly significant reduced in comparison with untreated infested soil. Soil borne propagules of fungi that are subjected to sublethal heat effects during solarization appear to have an increased sensitivity to antagonistic fungi and to bacteria which are less affected by soil solarization (Lifshitz et al. 1983). Stapleton and DeVay (1982) indicated that immediately after soil solarization, the population densities of "total" fungi were reduced by 85 to 90 percent in different experimental plots. However, population densities of thermotolerant and thermophilic microorganisms remained relatively high following solarization, and increased to levels higher than present in non-solarized soil. Stapleton and Devay (1986) mentioned that soil solarization has been effective as a pre-plant and as a post plant treatment, and has been compatible with chemical soil treatments and also biological soil amendments after solarization. Concerning to fungal counts determined either 30, 60 or 90 days from planting under greenhouse conditions. Solarization treatment caused a highly significant reduction in fungal counts in comparison with un-solarized one during the three time of sampling 30, 60 and 90 days after planting. The suppressive effect of solarization was more effective during the first 30 days of planting, and then it decreased gradually from 60 to 90 days after planting in comparison with untreated control. These results in harmony with those obtained by El-Shanawany et al. (2004), who reported that the composition of soil fungal community was altered in solarized soil. Both total count and number of fungal species detected were greatly reduced in solarized soil as compared to unsolarized soil. Plant pathogenic fungi are among the most sensitive soil borne organisms to soil solarization, especially species that are unable to grow at temperatures higher than 30° to 33°C (Stapleton & DeVay, 1982). Sublethal temperatures also may cause delays in germination of propagules and reduced virulence in host plants that vary with temperature and the duration of exposure. Pullman et al. (1981) found that these effects of sublethal temperatures were most pronounced when the fungi were exposed to temperatures of 37° to 39°C. The longer a propagule was exposed to sublethal heating, the longer was the time required for germination. They suggested that this relationship indicates that heat damage accumulates gradually to a point beyond which the propagule cannot recover. During sublethal heating; all living cells produce heat shock proteins (Plesofsky-vig & Brambl, 1985). Heat shock proteins are associated with the acquistion of thermotolerance or thermos/ability; however, fungi have a transient heat shock response that is shortlived, even if they are maintained at high temperature (Plesofsky-vig & Brambl, 1985). The overall effect of heat shock proteins on the survival of fungi during soil solarization is unknown. Other effects of sublethal heating are well documented, especially in the case of fungi produced sclerotia such as *Sclerotium cepivourum* and *S. rolfsii* where the rind of sclerotia becomes cracked resulting in increased leakage of various substances (Lifshitz et al., 1983). Greenberger et al. (1984) stated that many plant pathogenic fungi are differentially sensitive to moist heat and have been controlled by soil solarization.

They added that after soil solarization the propagules and weakened sclerotia of the most fungal population are intensely colonized by *Trichoderma harzianum* and other micro-organisms. Entwistle and Munasinge (1990) found that *S. cepivorum* exposed to sublethal temperatures, 35 or 40°C for 3 to 7 or 24 to 48 h, respectively, were colonized by bacteria and fungi, mycelium production in agar was delayed and the colonies were smaller compared with unexposed sclerotia; survival and germination in soil were also reduced. Regard for total bacteria and actinomycetes population count, obtained results raveled that population densities of bacteria and actinomycetes population count were significantly reduced in solarized soil and most reduction of total count occurred in the first 30 days. Stapleton et al. (1985) reported that soil solarization is a special mulching process which causes hydrothermal disinfestation and other physical and biological changes in soil which are beneficial to plant health and growth. Plastic film laid over moist soil during periods of high air temperature, usually for 1–2 months, can greatly reduce or eradicate a number of pathogens and pests including fungi, bacteria, nematodes, arthropods and weeds. However, the total count of bacteria and actinomycetes was significantly increased in solarized soil after 60 days then it rapidly increased at the 90 days interval. All tested dipping treatments caused significant increasing of bacterial and actinomycets count during the three timing intervals in comparison with un-treated control in both solarized and un-solarized treatments. Recolonization of solarized soils includes saprophytic bacteria which have less stringent nutritional requirements than plant pathogens (Misaghi & Grogan, 1969). These results were in harmony with several investigators. Stapleton and DeVay (1984) declared that populations of bacteria, including *Bacillus* species and actinomycetes may be reduced during solarization of soil compared with non-solarized soil. Stapleton and DeVay (1984) showed that solarization increased the total numbers of bacteria and actinomycetes in soil. Surprisingly, after solarization, *Pseudomonas* species quickly recolonize the soil and their populations reach high levels (Gamliel et al., 1987). Of great significance is the change in populations of *Bacillus* species during solarization; the percentage of colonies in solarized soil increased nearly 20-fold when compared with non-solarized soil (Stapleton & DeVay, 1984). These bacteria are among those which are rhizosphere competent and are believed to contribute to the increased growth response of plants grown in solarized soil (Katan, 1987). There were direct Effects of soil solarization on microorganisms such as, the inability of organisms to tolerate high temperatures is related to an upper limit in the degree of fluidity of membranes, beyond which breakdown of membrane function may be associated with membrane instability (Sundarum, 1986). Additional causes for the thermal decline of microorganisms at high temperatures involve the sustained inactivation of respiratory enzymes (Sundarum, 1986). As well as, there were indirect effects of soil solarization on microorganisms for examples, cells of plant pathogens weakened by heat stress are more vulnerable by several orders of magnitude to soil fumigants, to

antagonistic micro-organisms which are more able to tolerate high soil temperatures, and to changes in the gas environment which may develop during soil solarization. Also, changes occur in the structure or filth of soil during solarization, in soluble mineral substances available for plant and microbial growth, and in the populations of soil borne micro-organisms (Stapleton & DeVay. 1984). These changes affect the inoculum density of plant pathogens, and also their aggressiveness and survival. Changes in the populations of other soil borne micro-oganisms occur during and after solarization which may influence the disease suppressiveness of soil and also the increased plant growth response associated with solarized soils (Stapleton et al., 1985).

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