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Short Term Soil Solarization and Sclerotial Germination Stimulants as Control Measures against White Rot Disease in Onion Plants under Naturally Infested Field Conditions

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ABSTRACT

The impact of short term soil solarization (STSS) and sclerotial germination stimulants (SGS) to reduce the density of the sclerotial population of *Stromatinia cepivora*, and white rot disease of onion plants have been studied under field conditions. In laboratory tests, the mycelium of *S. cepivora* was killed when exposed to hot water for 20 and 1.0 min. at 56.0 and 59.0ºC respectively. The fungal sclerotia were killed when exposed to hot water for the same times at 61.0 and 64.0ºC, respectively. The summer of 2022 the application of the 15-day soil solarization effect on sclerotial viability in a field setting. The findings showed that at 10, 20, and 30 cm depths, respectively, soil solarization decreased the sclerotial viability by 75.0%, 68.9%, and 64.2% respectively. At zero time before application of sclerotial germination stimulants, there were 170 viable sclerotia/kg of soil in solarized soil (ss) and 520 viable sclerotia/kg of soil in un-solarized (us) soil. The viability of sclerotia was shown to be lower in solarized soil than in un-solarized soil when all sclerotial germination boosters were applied. With allium wastes, the viability was reduced by 92.7%, the greatest reduction was achieved. Subsequently by ss+ onion oil and ss + garlic oils which decreased viability by 87.9 and 86.7 % respectively. As for white rot, the results showed that in solarized soil as compared to un-solarized soil, all sclerotial germination stimulants were more successful. The most successful treatment, which decreased white rot disease by 90.3%, is ss + Allium wastes. Followed by ss + onion oil and ss+ garlic oil which reduced disease incidence by 84.7 and 85.8 % respectively. In soil that had been solarized as opposed to soil that had not, all sclerotial stimulants performed better. The most successful treatment is ss + Allium wastes, which resulted in a 221% increase in onion yield.

Keywords: Soil solarization, Sclerotial germination stimulants, white rot, onion plants, yield.

1. Introduction

The white rot disease caused by *Stromatinia cepivora* (Berk.) Whetzel, is considered a highly destructive factor to onion production (Elshahawy *et al.,* 2017a,b). The pathogen resides in the soil as sclerotia these sclerotia makes them resilient to harsh environments, allowing fungi to survive in the soil for up to 40 years (Alexander and Stewart, 1994). Numerous research studies have attempted to control the disease through biological means, aiming to enable the growth of onions without the need for additional chemicals. However, these approaches have not proven effective when *S. cepivora* populations are high (Elshahawy *et al.* 2017a; 2017b; 2018a; 2018b; 2019; Elshahawy and Saied-Nehal, 2021).

In Egypt, during the hot summer months when temperatures are high, the process of soil solarization has been shown to effectively reduce the occurrence of white rot disease in the field (Satour *et al.,* 1989; Basallote- Ureba and Melero-Vara, 1993).

Elevated temperatures resulting from solarization could potentially eliminate *S. cepivora* sclerotia found on the soil surface. However, as soil depth increases, solarization's ability to destroy this sclerotia declines (Katan, 1981; Satour *et al.,* 1989). A novel alternative management method

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called "soil biosolarization" effectively addresses soil-borne fungus by combining soil solarization and soil biofumigation (Rosskopf *et al.,* 2020). Prior to solarization, bio-solarization as organic additives in the soil that raises soil temperature by boosting microbial activity (Simmons *et al.,* 2013 and Elshahawy and Saied-Nehal, 2021).

Elshahawy and Saied-Nehal, (2021), discovered that fresh amendments of horse, chicken, or cow dung, cruciferous plant residues, or allium waste were used to bio-fumigate the soil. They added that in areas extensively infested with *S. cepivora*, these treatments increased the yield of onions and garlic by dramatically reducing the incidence of white rot disease when compared to the non-treated control.

The root exudates of Allium root exudates contain alkyl and alkenyl-L-cysteine sulphoxides, which soil microorganisms convert into volatile thiols and sulphides. This process stimulates the dormant sclerotia in soil (Coley-Smith, 1990).

Elshahawy *et al.* (2019) conducted a study that built upon previous research, which had found that White rot symptoms in future garlic and onion crops planted about a year after soil treatment were lessened by sclerotial germination boosters than by the control. Even though the sclerotial germination stimulants were successful in lowering viable sclerotia populations in soil with a high inoculum density (594.7 sclerotia/kg of soil), the pathogen still produced severe white rot and production losses in these subsequent crops.

The Aim of this study was to evaluate the effects of sclerotial germination stimulants and short-term soil solarisation, on white rot disease of onion plants under field conditions.

2. Materials and Methods

2.1. Isolate and production of sclerotia

One virulent isolate of *S. cepivora* obtained from onion plants infected with white rot in the author's previous work (Elshahawy *et al.* 2017a, b, 2018a, b, 2019 and Elshahawy and Saied-Nehal, 2021) was used to prepare sclerotial inoculum. The method outlined by Coley Smith, (1985) was followed to produce fungal sclerotia. The mycelium of *S. cepivora;* was grown on potato dextrose agar (PDA) medium; and then used to artificially infect onion bulbs. The bulbs were then incubated at 15°C in damp sand. The newly grown sclerotia were harvested after around five weeks, combined with sand (10 sclerotia/g of sand), and kept in soil for eight weeks at 20°C and then eight weeks at 5°C in nylon mesh bags (0.1 mm mesh size, 10 × 10 cm) (Gerbrandy, 1992). There were roughly 5g of sclerotial isolate inoculum in each bag.

2.2. Laboratory experiment

2.2.1. Impact of hot water treatment on viability of *S. cepivora* mycelium

Agar disks containing mycelia were tested for fungal viability using the protocol outlined by Whiting *et al.* (2001). Grown agar disks were exposed to various temperatures and times using a digital hot water bath (Neslab GP-300 Series Constant Temperature Bath, Union City, CA). Glass vials with screw caps, measuring 20cm in length and 20mm in diameter, filled with 20.0 ml of sterilized water were positioned in the water path at various temperatures.

Agar disks with a 6-mm diameter mycelia were placed in the screw-cap glass vials; and exposed to temperatures of 25, 50, 53, 56, 59, 62, and 65ºC for varying times, (5, 10, 15, 20, 25 and 30 minutes). After treatment, sterilized filter paper was used to dry the agar disks before transferring them into Petri-plates containing PDA media. Five replicates were used for each treatment. The viability of mycelia from agar disks were tested by placing the treated disks on PDA medium and incubating them at 20ºC for five days. The growth or lack thereof on the disks was noted for each treatment.

2.2.2. Impact of hot water treatment on sclerotia viability

In accordance with the procedure outlined by Coley-Smith *et al.* (1987), *S. cepivora* sclerotia were extracted from infested soil (after two months) and their surfaces were cleaned with 70% ethanol for three seconds before being thoroughly rinsed with sterile water. The sclerotia were then placed in glass vials in a water bath and exposed to varying temperatures (25, 50, 53, 56, 59, 62, and 65ºC) for durations of 5, 10, 15, 20, 25, and 30 minutes. Sterilized filter paper was used to dry the treated sclerotia before they were transferred to Petri-plates with PDA media. Each Petri plate contained ten

sclerotia evenly spaced across its surface. The plates were then incubated at 20ºC for five days. After this incubation period, sclerotia were considered to have germinated if white, mycelium-like *S. cepivora* growth was visible. The percentage of sclerotia that germinated was then calculated.

2.3. Field experiments

2.3.1. Extraction of sclerotia from soil and testing their viability

Extraction of sclerotia from soil was conducted using a wet-saving floatation method established by Utkhede and Rahe (1979). The sclerotia were surface sterilized in 70 % Ethanol for 1 minute, washed in distilled water and dried using sterilized filter papers then plated on potato dextrose agar Petri dishes (Crowe *et al.,* 1980). Petri dishes incubated at 20ºC for 15 days and examined at 10x magnification with a stereo microscope.

2.3.2. Applications of short term of soil solarization

Soil solarization was applied for 15 days from 15-29 Augsts 2022. A field in the El-Qalubia governorate, Egypt was chosen for this study. This field was known high infestation level of *S. cepivora* (600 sclerotia/kg of soil) (Elshahawy *et al.,* 2019). Sclerotia were calculated using a wet-saving flotation technique created by Utkhede and Rahe (1979).

2.3.3. Impact of short term soil solarization on soil temperatures and sclerotial viability under field conditions during summer season

Impact of soil solarization on the viability of *S. cepivora* sclerotia were tested. Every experimental field was divided into six plots, each 6.0x21.0m with 1.0m border between them. Each plot was further divided longitudinally into two sub plots. The half subplots, each measuring 3.0×10.5m, were randomly mulched with transparent polyethylene sheets that were 200 µm thick.

2.3.4. Impact of soil solarization on soil temperature

The soil temperatures were consistently recorded daily in both solarized and un-solarized soil at depths of 1–10cm, 11–20cm and 21–30cm using a soil thermograph. Throughout the mulching period, the average temperature was recorded.

2.3.5. Effect of soil solarization on sclerotia viability

Determination of *S. cepivora* sclerotia viability during a two-week solarization, nylon mesh bags were artificially infested with 100 sclerotia of *S. cepivora* /100g. Before soil mulching, these nylon bags were incorporated. Determination of Sclerotia viability during the solarisation period, the experimental field soil was placed in the centre of the corresponding replicated plots at three different depths (10, 20, and 30 cm in both solarised and un-solarized soil.

2.3.6. Application of germination stimulants after soil mulching period

Germination stimulant materials, such as onion oil (OO), garlic oil (GO) and Allium wastes (AW) were obtained from El-Nenaiea Company (Kafr Abu Mahmoud, Ashmoun, Menofia, Egypt). The fungicide Folocure was used as a reference for the applied materials. Untreated soil was kept as control treatment. All these treatments were applied to both solarized and un-solarized soil to study their effects on sclerotial viability, white rot of onion and yield.

In field trial all treatments were carried out in solarized or un solarized soil. Each of the six blocks that made up the experimental area measured 3.0 x 57.0m, with 6.0m separating them. Six plots, each measuring 3.0 × 3.5 m, were created from each block. To avoid cross-contamination of the volatile substances, a 6-meter boundary was placed between each plot in every instance. The following treatments were applied at random to these plots:

1-Solarized soil(ss) + onion oil (oo), 2- solarized soil + garlic oil (go), 3- solarized + Allium wastes (aw), 4- solarized +fungicide, 5- solarized only,6-oo,7-go,8- aw, 9- fungicide, 10- control (untreated). Sclerotial germination stimulants were applied in both solarized and non-solarized soil.

Randomized block designs with five replications per treatment made up the experimental field design. A 1000 kg/ha addition of solid stimulants and a 10 L/ha application of liquid stimulants were made to the soil. Prior to sowing wheat plants, all stimulants were administered on November 1, 2022.

2.3.7. Impact of short term of solarization and sclerotial germination stimulants on white rot incidence of onion plants

The following treatments were applied in field to study their impact on onion white rot disease and yield during the growing seasons:

1	Solarized soil + OO,	**6**	OO only,
2	Solarized soil + GO,	**7**	GO only,
3	Solarized + AW	**8**	AW only,
4	Solarized + fungicide,	**9**	Fungicide,
5	Solarized only,	**10**	Untreated control

On November 1, 2023, the plots were ready for the planting of onions. Each plot's soil was tilled and spaded by hand. For each treatment short-term solarisation, non-solarized soil, germination stimulant, and untreated controls three replicated plots were utilised. Each plot had six rows, each measuring 3.0 m in length and 50 cm in breadth, and the plot size was 3.0 x 3.5 m. Transplants of 60-day-old onions (cv. Giza red) were placed 10 cm apart in each row.

Onion was grown to maturity followed onion traditional production regimes during November 2023 to May 2024. White rot disease estimation was recorded regularly during the growing season.

The percentage of infected plants was calculated according to Elshahawy *et al.* (2017a) as follows:

White rot infection % = Number of infected plants /Total number of plants x100

Whit rot reduction % = % of White rot % in control- White rot % in treatment White rot % in control

2.3.8. Effect of short term of solarization and sclerotial germination stimulants on bulb yield of onion plants

Onion bulbs were harvested and weighed (kg/plot).

2.4. Statistical analysis:

Neler *et al.* (1985) used the Tukey test for multiple comparison among means.

3. Results

3.1. Laboratory experiment

3.1.1. Impact of hot-water on viability of *S. cepivora* fungus

Agar disks containing *S. cepivora* mycelia were subjected to varying temperature conditions, such as 25, 50, 53, 56, 59, 62, and 65 °C, and varied exposure times, such as 5, 10, 15, 20, 25, and 30 minutes. Data in Table (1) show the lethal temperature to *S. cepivora* were 56.0 and 59.0oC when exposed for 20 and 1.0 min. respectively.

Table 1: Impact of hot water and exposure times on mycelial growth

Hot water (ºC)	Viability of *Stromatinia cepivora* mycelia agar disks: Exposure time (minutes)			
	1	**10**	**20**	**30**
25	+*	+	+	+
50	+	+	+	+
53	+	+	+	+
56	+	+	—	—
59	**—	—	—	—
62	—	—	—	—
65	—	—	—	—

* Visual growth, ** No visual growth

3.1.2. Effect on sclerotia agar disks

Data in Table (2) show that the lethal temperatures of hot water to *Sclerotia* of *S. cepivorum* were 61.0 and 64.0 ºC when exposed for 20 and 1.0 min. respectively.

Table 2: Impact of hot water and their exposure times on sclerotial viability

Hot water (°C)	Viability of *Stromatinia cepivora* Sclerotia Exposure time (minutes)			
	1	10	20	30
25	+	+	+	+
50	+	+	+	+
53	+	+	+	+
56	+	+	+	+
59	+	+	+	+
62	+	+	—	—
65	—	—	—	—

* Visual growth , ** No visual growth

3.2. Field experiments

3.2.1. Impact of short term soil solarization on soil temperatures and sclerotial viability under field conditions during summer 2022

Field experiments (600 sclerotia/kg of soil) were conducted during the summer of 2022.

3.2.2. Impact on soil temperatures

Results in Figure (1) show that, in comparison to un-solarized soil, the maximum soil temperatures in solarized soil increased by 18.0, 15.3, and 12.0 °C at depths of 1-10, 11-20, and 21-30 cm of soil surface respectively. Solarized soil had the high increase in soil temperature, with maximum soil temperatures at three depths of 60.0, 56.0, and 50.0 °C, respectively.

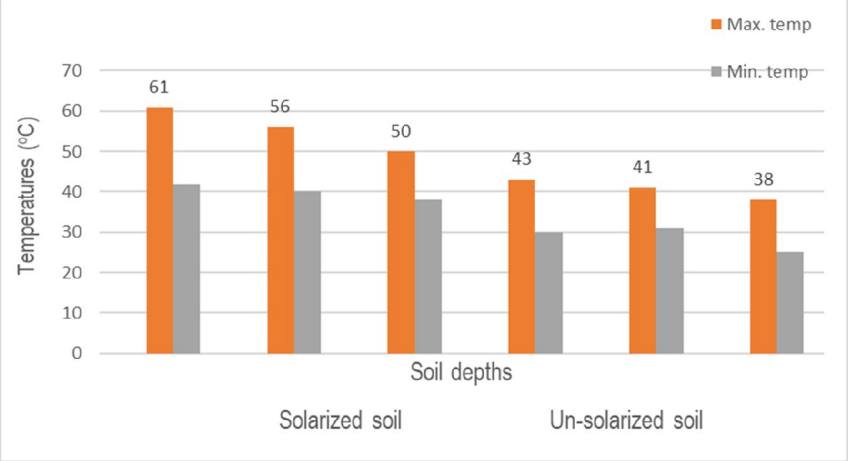

Fig. 1: Effect of short term soil solarization on soil temperatures under field conditions during summer season

3.2.3. Effect on sclerotia viability

The summer of 2022 the application of the 15-day soil solarization effect on sclerotial viability in a field setting. The sclerotial viability was decreased by all treatments, according to the results in (Fig. 2). At 10, 20, and 30 cm depths, the sclerotial viability was decreased by 75.0, 68.9, and 64.2%, respectively, due to soil solarization. In contrast to viability at the beginning of the experiment, non-solarized soil decreased sclerotial viability by 12.0, 10.0, and 5.0% at 10, 20, and 30 cm depths, respectively.

3.2.4. Testing of sclerotial germination stimulants during 2022/2023 seasons

SGS i.e., onion oil(OO), garlic oil (GO) and Allium wastes (AW), Folcure (fungicide) and control (untreated) were applied in solarized soil(Ss) for 15 days or in un-solarized soil (USs) to study their effects on sclerotial viability, white rot of onion and yield.

3.2.5. Effect of germination stimulants on sclerotial viability

At the zero time of the first treatment, there were 170 viable sclerotia /kg of soil in solarized soil (ss) and 520 viable sclerotia /kg of soil in un-solarized (us) soil. Table (3 and Fig 3.) results show that the viability of sclerotia was lower in solarized soil than in un-solarized soil for all sclerotial germination stimulants. Allium wastes resulted in the largest reduction as 92.7 % viability of sclerotia. Followed by ss+ onion oil and ss+ garlic oil which reduced viability by 87.9 and 86.7 % respectively. Meanwhile, in un-solarized soil Allium wastes and Fungicide reduced the viability by 58.0 and 56.0 % respectively. While onion oil and garlic oil reduced viability by 40.0 and 44.0% respectively.

Table 3: Impact of STSS and SGS on Sclerotia germination

Treatments	Viable sclerotia /kg soil			
	Sampling date (month)			
	0.0	3	6	Reduction %
	Soil solarization			
Ss + Onion oil (OO)	170c	70f	20 e	87.9
Ss + garlic oil (GO)	155c	75f	22 e	86.7
Ss + Allium wastes (AW)	160c	50f	12.0f	92.7
Ss + Folcure (fungicide)	165c	160e	140d	15.0
Solarization (Ss) only	170c	165e	165 d	0.0
	Un- soil solarization			
Onion oils (OO)	510a	400b	300b	40.0
Garlic oil (GO)	500a	405b	280b	44.0
Allium wastes (AW)	498a	355c	210c	58.0
Folcure (fungicide)	210 b	200d	220c	56.0
Control (untreated)	520a	502a	500a	0.0

Figures with the same letter are not significantly different (P = 0.05)

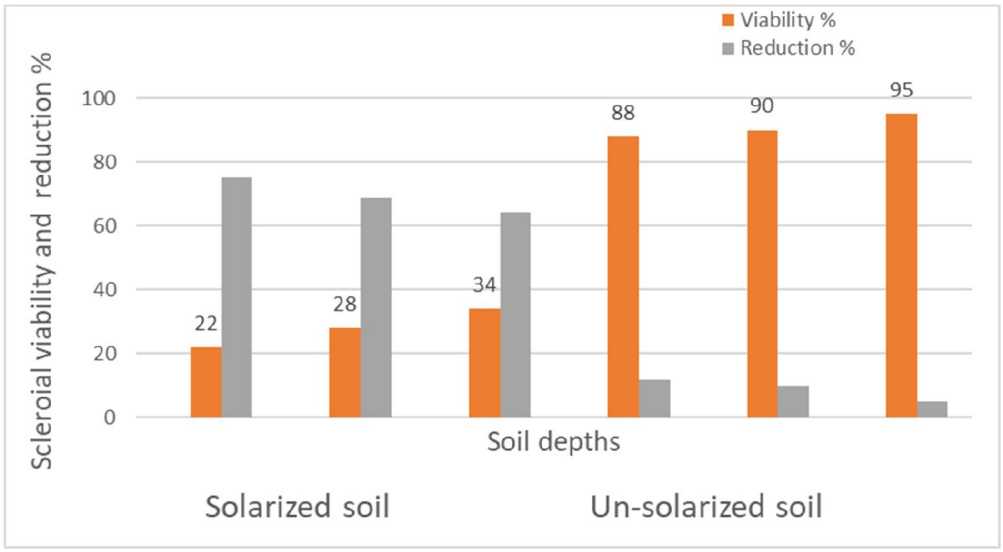

Fig. 2: Impact of short term soil solarization on sclerotial viability and their reduction during summer season

3.2.6. Impact of STSS and SGS on white rot of onion plants

Results in Table (4) show that during two field experiments the white rot disease of onion plants was greatly decreased by all tested treatments. In comparison to un-solarized soil, all sclerotial germination stimulants performed better in solarized soil. ss+ Allium wastes are the most effective treatment, reducing white rot illness by 90.3%. SS+onion oil and SS+garlic oil came next, reducing the disease incidence by 84.7 and 85.7 % respectively. The greatest reduction in disease incidence in unsolarized soil was achieved by using fungicide and allium wastes, which decreased white rot by

66.5% and 68.2%, respectively. Onion oil and garlic oil, decreased the disease incidence by 52.3 and 50.6%, respectively.

Table 4: Impact of short term soil solarization and sclerotial germination stimulants alone or in combination on onion white rot disease during tow field experiments

Treatments	Onion white rot disease incidence %			
	Exp.1	Exp.2	Mean	Efficacy %
	Soil solarization			
Ss+Onion oil (oo)	14.0 d	13.0f	13.5e	84.7
Ss+ garlic oil (go)	12.0 d	13.0f	12.5e	85.8
Ss+ Allium wastes	8.0 d	9.0 g	8.5f	90.3
Ss+Folcure (fungicide)	18.0 b	18.0e	18.0d	79.5
Solarization only	45.0 b	51.0b	48.0b	45.5
	Un- soil solarization			
Onion oils (oo)	40.0 b	44.0 c	42.0b	52.3
Garlic oil (og)	42.0 b	45.0 c	43.5b	50.6
Allium wastes	25.0 c	31.0 d	28.0c	68.2
Folcure (fungicide)	27.0 c	32.0 d	29.5c	66.5
Control (untreated)	86.0 a	90.0 a	88.0a	00.0

Figures with the same letter are not significantly different (P = 0.05)

3.2.7. Impact of short term of solarization and germination stimulants on bulb yield

In two field tests, the onion yield was considerably enhanced by each of the tested treatments, according to the results shown in Table (5). When soil was solarized as opposed to not, all sclerotial stimulants performed better, ss+ Allium wastes increased the onion yield by 221%. After that, the onion yield was raised by 123.2, 132.1, and 123.2 %, respectively, using ss+onion oil, ss+garlic oil, and ss+fungicide. Among allium wastes, onion yield increased by 83.9% in unsolarized soil, the greatest increase. Other treatments showed moderate effect.

Table 5: Impact of STSS and SGS on onion yield in the two field experiments

Treatments	Onion yield (Ton/ fedan)			
	Exp.1	Exp.2	Mean	Increase %
	Soil solarization			
Ss + Onion oil (OO)	12.0 b	13.0 b	12.5b	123.2
Ss + garlic oil (GO)	13.0 b	13.0 b	13.0b	132.1
Ss + Allium wastes (AW)	17.0 a	19.0 a	18.0 a	221.0
Ss+Folcure (fungicide)	13.0 b	12.0 b	12.5b	123.2
Solarization only	8.6 e	8.0 e	8.3d	48.2
	Un- soil solarization			
Onion oils (OO)	8.0 d	8.4 d	8.2d	46.2
Garlic oil (GO)	8.2 d	9.2 d	8.7d	55.4
Allium wastes (AW)	10.0 c	10.5 c	10.3c	83.9
Folcure (fungicide)	8.0 d	8.4 d	8.2d	46.2
Control (untreated)	5.5 f	5.7 f	5.6e	0.0

Figures with the same letter are not significantly different (P = 0.05)

4. Discussion

Onions (*Allium cepa* L.) are two of Egypt's most significant vegetable crops, grown both domestically and exported. *Stromatinia cepivora* (Berk.) Whetzel, causes white rot disease, is a danger to production (Elshahawy *et al.,* 2017a, b).

Recent years have seen the detection of white rot disease in El-Qalubia, governorate (Elshahawy *et al.,* 2018a,b, 2020) Elshahawy and Saied-Nehal, 2021), where repeated farming of onion and garlic typically results in complete crop failure due to the infestation of multiple *S. cepivora* sclerotia in the soil.

The pathogen lives in the soil and on infected Allium plant waste as sclerotia. These sclerotia enabling fungi to survive in the soil for up to 40 years (Alexander & Stewart, 1994).

Numerous studies have employed biological techniques to manage disease in order to produce

onions and garlic without the need for additional chemicals, but these techniques did not produce satisfactory results when *S. cepivora* was present at high inoculum densities (Elshahawy *et al.* 2017a,b, 2018a,b, 2019) Elshahawy and Saied-Nehal, (2021).

Soil solarization significantly decreased white rot disease under Egyptian conditions, which as high summer temperatures (Satour *et al.,* 1989 and Elshahawy and Saied-Nehal, 2021).

The current study's laboratory experiment results showed that agar disks containing *S. cepivorum* mycelia were examined at various temperatures *i.e.*25, 50, 53, 56, 59, 62, and 65 °C and for varying exposure times *i.e.*5, 10, 15, 20, 25, and 30 minutes. The deadly temperatures of hot water declined as exposure times increased, according to the results. *S. cepivorum* could only survive at temperatures of 56.0 and 59.0 degrees Celsius for 20 and 1.0 minutes, respectively. Regarding sclerotia, after being exposed for 20 and 1.0 minutes, respectively, the lethal temperatures of hot water for *S. cepivorum* sclerotia were 61.0 and 64.0 °C. According to Sundarum (1986), organisms' incapacity to withstand high temperatures is linked to a maximum level of membrane fluidity, beyond which a breakdown in membrane function may be linked to membrane instability. The prolonged inactivation of respiratory enzymes is one of the additional reasons why bacteria thermally degrade at high temperatures (Brock, 1978 and Sundarum, 1986). These are the primary results of high soil temperatures, and they are mostly responsible for the decline in weed seed and soil-borne microorganism populations.

Elevated temperatures resulting from solarization could potentially eliminate *S. cepivora* sclerotia found in higher soil layers. Nevertheless, the efficiency of solarization in eliminating this sclerotia declined as soil depth increased (Katan, 1981; Satour *et al.,* 1989).

Solarization involves covering damp soil with clear polyethylene plastic in the sweltering summer months, which raises soil temperatures to a point where many weeds, nematodes, and soil-borne plant pathogens become fatal (Farag and Fotouh, 2010; Abd-Elgawad *et al.,* 2019 and Elshahawy and Saied- Nehal, 2021).

Over a few weeks, heating the surface soil can help manage harmful fungus and reduce plant diseases brought on by fungi that are carried by the soil (Culman *et al.,* 2006; Farag and Fotouh, 2010; Elshahawy and Saied- Nehal, 2021). According to Ndiaye *et al.* (2007), solarization raises the soil's temperature to about 50 °C for at least four hours each day, which significantly reduces the *M. phaseolina* soil inoculum by 44%.

In the current study, the results showed that, in comparison to un-solarized soil, the maximum soil temperatures in solarized soil increased by 18.0, 15.3, and 12.0 °C at depths of 1–10, 11–20, and 21–30 cm of the surface. In contrast to viability at the beginning of the experiment, non-solarized soil decreased sclerotial viability by 12.0, 10.0, and 5.0% at 10, 20, and 30 cm depths, respectively. When compared to un-solarized soil, soil solarization dramatically decreased white rot disease.

In this respect Elshahawy and Saied-Nehal (2021) found that, at 10, 20, and 30 cm depths, respectively, solarization alone decreased the sclerotial viability.

Sheikh and Ghaffar (1984) discovered that solarizing soil naturally containing five to seven cyclocytes per gram of the fungus M. phaseolina for one week raised the temperature of the soil at a depth of 20 cm from 30 to 41 °C, which in turn reduced the mortality rate of Vigna plants from 20% to 0%. Adams (1987) found that 50% of *S. cepivorum* sclerotia may be killed in about 48 minutes at 50 °C. Furthermore, Entwistle (1990) discovered that, after a month of exposure, temperatures between 40 and 62 °C for a duration of 2 to 25 days were adequate to destroy the sclerotia of *S. cepivorum* in a pile of salad onions and cereal straw. According to Ndiaye *et al*. (2007), solarization raises the soil's temperature to about 50 °C for at least four hours each day, which significantly reduces the M. phaseolina soil inoculum by 44%.

The impacts of soil solarization are multifaceted, involving the direct thermal killing of pathogen propagules, the advantageous influence of microbial activity, and favorable modifications to the soil's chemical and physical characteristics (Katan, 1981). Furthermore, not all infections are under the control of solarization alone (Katan, 1981). The amount of volatile compounds released into the soil atmosphere beneath the plastic increases as a result of the high temperatures brought on by the covering (Gamliel & Stapleton, 1993 and Gamliel & Stapleton, 1995). This increase is due to a noticeable increase in the vapor pressure of volatile compounds present in the liquid or solid soil parts. This clarifies the detrimental impact on sclerotial viability, which was caused by an increase in soil temperature. According to Melero-

Vara *et al.* (2012), solarized soil amended with organic materials reduce the viability of soil-borne plant diseases by releasing toxic volatiles like nitrous acid and ammonia. Also, the use of a plastic cover alone significantly decreased the incidence of white rot infections. These outcomes concur with those that other workers have reported. Blok *et al*. (2000) discovered that root rot of asparagus fungi significantly decreased in survival when soil was treated with broccoli or grass and covered with plastic covers.

According to Coventry *et al*. (2005), adding 50% w/w of compost made from onion waste to the soil significantly decreased the amount of Allium white rot that affected onion seedlings in glasshouse pot experiments.

Ndiaye *et al*. (2007) found that treatments involving added millet residue or paunch with solarization decreased the root rot disease of cowpea plants.

Also, Klein *et al.* (2007) solarized soil had previously been amended with plant wastes, there was a decrease in Fusarium root rot.

Domínguez *et al.* (2014) came to the conclusion that using chicken manure to biosolarize soil is a viable, sustainable way to prevent black root rot in strawberries.

The process by which solarization inactivates pathogens may involve elements like the soil's high temperature. The survival and vigor of sclerotia in the soil are impacted when the plastic cover is applied, since it raises the temperature and inactivates pathogen propagules (Katan, 1981 and DeVay & Katan, 1991).

In addition to the direct cumulative heat damage, the buildup of volatiles and the interaction of numerous physical, chemical, and biological processes that take place under tarps may also have an impact on an environment that controls infections (Stapleton *et al.,* 2000; Fernandez-Bayo *et al.,* 2020).

According to reports, efforts against white rot disease in soil have concentrated on lowering *S. cepivora* sclerotia populations by SGS in the absence of Allium crops (Coley-Smith and Parfitt, 1986; Griinzweig *et al.,* 1993; Davis *et al.,* 2007 and Elshahawy *et al*., 2019). Without certain sulphides released from Allium crop roots, Sclerotia of *S. cepivora* can persist for 40 years and serve as an infection source (Coley-Smith, 1990).

According to the current study's results, the viability of sclerotia was shown to be lower in solarized soil than in un-solarized soil when all sclerotial germination stimulants were applied. Allium wastes resulted in the largest reduction in viability by 92.7 %. Followed by ss+ onion oil and ss+ garlic oil which reduced viability by 87.9 and 86.7 % respectively. Meanwhile, in un-solarized soil Allium wastes and fungicide reduced the viability by 58.0 and 56.0 % respectively. While onion oil and garlic oil reduced viability by 40.0 and 44.0 % respectively.

All sclerotial germination stimulants were more successful in solarized soil than in un-solarized soil when it came to the white rot of onion plants. ss+ Allium wastes are the most effective treatment; they reduced white rot disease by 90.3 % %. Conversely, the greatest disease incidence reduction in unsolarized soil was achieved using fungicide and allium wastes, which decreased white rot by 68.5 and 68.2 %, respectively.

In two field tests measuring onion yield, soil that had been solarized yielded higher yields from all sclerotial stimulants than soil that had not. With a 221 % increase in onion output, ss+ Allium wastes is the most effective treatment. The largest boost in onion yield in unsolarized soil was achieved with allium wastes, which raised yield by 83.9%.

After germination, its brief life depends on the right temperature and quantity of self-food; hence, if a host is not discovered, it will perish. When chemically added to soil, diallyl disulphide (DADS), a naturally occurring substance found in Allium spp. and its derivatives like onion and garlic oils, is thought to act as a natural sclerotial stimulant (Davis *et al.,* 2007 and Elshahawy *et al.,* 2019).

When this substance is applied to the soil without an allium crop present, 90–99% of the sclerotia will germinate (Hovius and McDonald, 2002; Davis *et al.,* 2007and Elshahawy *et al.,* 2019).

Elshahawy *et al.* (2019) found that SGS were superior to the control of white rot in onion and garlic crops.

The current study's findings are in line with earlier studies that examined the impact of SGS on sclerotia survival in treated mineral soils (Coley-Smith and Parfitt, 1986; Crow *et al.,* 1994 and Terry,

1996). Because SGS were applied in the absence of allium crops on the field. (Gerbrandy, 1992; Crowe and Hall, 1980). According to Crow *et al.* (1994), the sclerotial germination response is only very effective in the vicinity of the fungus's optimal temperature and soil moisture levels. Under field conditions, the impact of SGS on the incidence of white rot and the production of subsequent onions was investigated in the absence of Allium crops. High inoculum density correlated to a high percentage of dead plants, which is consistent with earlier indications (Crowe *et al.,* 1980;

Our findings appear to belong to the third kind, which is symbolized by Egyptian onion white rot. Stimulants for germination had a positive impact on the health of the plants and the yield of bulbs. In both field trials, germination boosters greatly enhanced onion production as compared to the untreated control. These outcomes concur with Davis et al.'s previous research (2007).

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