



Hot Water Treatment to Management Onion White Rot in Infested Soil with *Stromatinia cepivora* Fungus

Nehal Mohamed Saied

Department of Plant Pathology, Agricultural & Biological Research Institute, National Research Centre (NRC), 33 El-Buhouth St., 12622 Dokki, Egypt.

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ABSTRACT

Impact of hot water temperatures on *Stromatinia cepivora* fungus in vitro and white rot of onion plants in vivo was investigated. Agar disks containing *Stromatinia cepivora* mycelia were examined at various temperatures (25, 50, 52, 54, and 56 °C) and exposure times (5, 10, 15, and 20 minutes) using a digital water path. The results showed that the lethal temperatures for *S. cepivora* were 54.0 and 56.0 °C for 15 and 5.0 minutes, respectively. As for sclerotia, results indicated the lethal temperatures to Sclerotia of *S. cepivora* were 60.0 and 65.0 °C for 15 and 5.0 min. respectively. Moreover, several volumes of boiling water (100 °C) and varying degrees of hot water at 0.5 L/kg soil were investigated in pot tests to see how they affected soil temperatures, Sclerotia viability, and white rot disease of onion plants. The results showed that the greatest rise in soil temperatures was achieved with hot water at rates of 0.4 and 0.5 L/kg soil, resulted in increasing soil temperature to 80.5 and 85.0 °C, respectively, and increased soil temperatures with degrees of 90.0 and 100.0 °C at rates of 0.5 L/kg soil, to 73.0 and 84.0 °C, respectively. AS for the effect of hot water on Sclerotia germination of *S. cepivorum* studies revealed that boiling water at 0.4 and 0.5 L/kg soil and degrees of hot water at 90 and 100.0 °C completely inhibited sclerotia germination. The results of the onion white rot revealed that all tested volumes of boiling water or degrees of hot water considerably suppressed the percentage of white rot disease. White rot disease was completely suppressed by boiling water at 0.5 L/kg soil and hot water at 100.0 °C. The greatest reduction was achieved with hot water at 90 °C and boiling water at 0.4 L/kg soil, which inhibited white rot incidence and severity by 85.0 & 62.5 and 70.0 & 62.5%, respectively. Other treatments proved less effective. All tested volumes of boiling water or degrees of hot water significantly increased all tested vegetative characters of onion plants. Boiling water at 0.4 and 0.5 L/kg soil and hot water at 90 and 100.0 °C recorded the highest increase in all tested of vegetative characters.

Keywords: hot water, temperature, exposures time, onion plants, white rot disease, greenhouse

1. Introduction

Two of Egypt's most important vegetable crops are onion (*Allium cepa* L.) and garlic (*Allium sativum* L.), which are used both locally and for export (Anonymous, 2018).

White rot disease, caused by *Stromatinia cepivora* (Berk.) Whetzel, is the most dangerous disease that impacts garlic and onion crops. (Elshahawy *et al.*, 2017a,b, 2018a,b, 2020, Elshahawy and Saied-Nehal, 2021).

Elshahawy and Saied-Nehal, (2021) reported that when the soil is infested with *Stromatinia cepivora* sclerotia, repeated onion and garlic farming often ends in crops failure. In addition to pathogen is found in the soil as sclerotia, as well as in infected allium plant detritus. These sclerotia are structurally robust to hostile settings, allowing fungus flourish in soil to forty years (Alexander and Stewart, 1994).

Many studies have used biological ways to avoid diseases, allowing onion and garlic to be cultivated without the use of chemicals. However, these approaches failed to produce adequate results with highly

Corresponding Author: Nehal M. Saied, Department of Plant Pathology, Agricultural & Biological Research Institute, National Research Centre (NRC), 33 El-Buhouth St., 12622 Dokki, Egypt.

population of *S. cepivora* inoculum (Elshahawy *et al.* 2017a, b, 2018a, b, 2019) Elshahawy and Saied-Nehal, (2021).

Elshahawy and Saied-Nehal (2021) reported that the greatest suppression effect on *S. cepivora*'s sclerotial viability was caused by Allium wastes. These treatments also decreased the white rot in garlic as well as onion plants, increasing their yield in areas infested by *S. cepivora*. Alternative methods for white rot management have concentrated on lowering *S. cepivora* sclerotia populations by stimulating sclerotial germination when garlic and onion crops are not present (Coley-Smith and Parfitt, 1986; Elshahawy *et al.*, 2019). Sclerotia of *S. cepivora* live more than 40 years in the absence Allium crop and can serve as a sources to infect plants (Coley-Smith 1990). It is well known that hot water treatment can be used to eradicate seed infections, especially those brought on by phytopathogenic bacteria. Celery, lettuce, spinach, and carrots are less effective with this method than peppers, tomatoes, and cabbage (Miller, and Ivey, 2005 and Kim *et al.*, 2022). Significant research has recently been conducted to develop an economical and user-friendly apple fruit pre-storage hot water treatment (HWT) (Hosseinfarahi *et al.* 2020; Bhatta 2022).

According to Wassermann *et al.* (2019), in order to control postharvest degradation in fruits and vegetables, after-harvest hot water treatments (HWTs) are physical, nondestructive processes that do not leave any residue on the food (Strano *et al.*, 2022 and Elshahawy *et al.*, 2023). When hot water (95 to 100°C) is applied to the soil's surface, the temperature rises to a point where plant diseases, pests, and weed seeds can no longer survive (Kita *et al.*, 2003; Fujinaga, *et al.*, 2005 and Ogawara, *et al.*, 2006; Saied-Nehal 2011 and Mahdy *et al.*, 2011 and 2012).

According to Ogawara *et al.* (2006), this experiment was undertaken in 2003 to investigate the effects and sustainability of hot water treatment following a Fusarium wilt of melons in Ibaraki prefecture, Japan. This experiment was carried out in a greenhouse with Fusarium-infested soil in Murota City. A subsoiler worked the soil to a depth of 50 cm and treated it with 200 L/m² of hot water (95 oC). During the treatment, the soil was held at a high temperature (55 oC) and depth (30 cm). Following the treatment, no Fusarium was found in the soil at 10 cm depth, and Fusarium density was drastically reduced at 30 cm depth. Earl's Miyabi Shunju cultivar was planted in the treated area, and Fusarium wilt was detected at a rate of 0 to 0.5%.

Furthermore, Mahdy *et al.* (2011) observed that mycelial agar disks of root rot fungi were subjected to various temperatures of hot water in vitro. The data showed that growth suspension was more responsive to temperature and exposure durations than agar disks containing mycelia. All tested fungi were killed at 58.0 and 56.0 °C for one minute of hot water as mycelial disks or suspension, respectively. Boiling water at 0.4 and 0.5 l/kg soil, as well as hot water at 90.0 and 100 °C at 0.5 l/kg soil, resulted in a complete inhibition of total count of all fungi. In terms of disease incidence, boiling water at rates of 0.4 and 0.5 l/kg soil and hot water at 90.0 and 100 °C (0.5 L/kg soil) suppressed root rot more than 88.4 and 92.9%, respectively.

Also, Saied-Nehal. (2011) reported that this study assessed the use of hot water sprinkler or buried pipe system, for managing cucumber root infections in pot and commercial greenhouse environments. Cloth bags were experimentally infested with pathogenic fungi, i.e., *Rizoctonia solani*, *Fusarium solani*, *Sclerotium rolfsii*, and *Pythium ultimum*, and buried at three depths of the soil surface, i.e., 1-10, 11-20, and 21-30 cm, before soil treatments. The results showed that the Buried pipes system reduced the total count of all tested fungi at all depths, but the Sprinklers system was active at all depths except 21-30 cm below the soil surface of *F. solani* and *P. ultimum* fungi. Actinomycetes demonstrated greater heat tolerance than fungal plant diseases, although bacteria showed intermediate tolerance to hot water and soil solarization. Under plastic house conditions, the results showed that hot water as a Buried pipes system provided complete protection against root rot disease for 2.0 hours when applied once or twice, as well as hot water as a Sprinklers system at a rate of 40 L/m² and Basamid when applied twice. Soil solarization (once applied) resulted in a moderate reduction in root rot, which decreased by 76.7%.

The aim of this research is studying the impact of hot water treatments on *S. cepivora* fungus in vitro and onion white rot disease under greenhouse conditions.

2. Materials and Methods

2.1. Laboratory experiments

2.1.1. *Stromatinia cepivora* fungus

Isolate of *Stromatinia cepivora* (Berk.) Whetzel, obtained from infected onion plants with white rot in the author's previous work (Elshahawy *et al.* 2017a, b, 2018a, b, 2019 and Elshahawy and Saied-Nehal, 2021).

2.1.2. Impact of hot water treatments on *S. cepivora* fungus

Viability of agar disks containing mycelia was determined according (Whiting *et al.* (2001). A digital hot water bath was used to examine growth agar disks at different temperatures and exposure periods. Twenty centimeter long by twenty millimeter in diameter screw-cap glass vials holding 20.0 ml of sterile were placed in the water channel at various temperatures. The grown edge of 10-day-old *S. cepivora* cultures were cultured on PDA media was used to cut agar discs with mycelia measuring 6 mm in diameter. At 25 oC, 50 oC, 52 oC, 54 oC, and 56 oC, for exposure periods of 5, 10, 15, and 20 minutes, respectively. Treated agar discs were dried on sterile filter paper and transferred to Petri dishes with PDA media. Each treatment involved the use of five replicates and three disks. treated disks were cultured on PDA medium and incubating for 5 days at 20 °C. Viability of mycelia of agar disks demonstrating growth or non-growth were recorded.

2.1.3. Impact on sclerotia of *S. cepivora*

Sclerotia of *S. cepivora* were collected from infested soil (after two months) using the procedure outlined by Coley-Smith *et al.*, (1987), and the surface was disinfected with 70% ethanol alcohol for 3 seconds before being washed several times with sterilized water. Sclerotia were transported to glass vials using a digital water route at of 25, 50, 55, 60, and 65 oC for varying exposure times of 5, 10, 15, and 20 minutes. After drying on sterile filter paper, all sclerotia treated or not were put into Petri dishes with PDA medium. Each Petri plate had ten sclerotia uniformly spaced over its surface. For five days, the plates were incubated at 20 degrees Celsius. After five days, sclerotia were deemed to have germinated if the white mycelium that is typical of *S. cepivorum* appeared. There was a reported percentage of sclerotia germination

2.2. Pot Experiments

2.2.1. Onion seedlings

Onion seedlings (cv. Giza red) obtained from Vegetables Crop Research, Agricultural Research Centre, Giza, Egypt were used in this study.

2.2.2. Impact of hot water soil treatments on white rot disease

In pot tests, different volumes of boiling water (100 °C) soil treatments and varying degrees of hot water at 0.5 L/kg soil were investigated to see how they affected soil temperatures, sclerotia germination, and white rot disease in onion plants.

2.3. Effect of hot water on soil temperatures

2.3.1. Impact of boiling water on soil temperatures

Various volumes of hot water (95-100 °C), i.e. 0.0, 0.2, 0.3, 0.4, and 0.5 L/kg soil, were used as soil treatments to investigate their impact on soil temperature. Plastic pots with sandy loam soil (30 cm diameter and 5.0 kg soil) were utilized. Three thermometers were used to record soil temperatures one minute after hot water treatment, and the minimum temperature was established.

2.3.2. Impact of hot water temperatures (0.5 L / kg soil) on soil temperature

To evaluate the effect on soil temperatures, several degrees of hot water temperatures were applied at a rate of 0.5 L/kg soil, namely 30.0, 70.0, 80.0, 90.0, and 100.0 °C. Three thermometers were used to measure soil temperatures one minute after hot water treatments, and the minimum temperature was determined.

2.4. Effect of hot water on sclerotia germination of *S. cepivora*

2.4.1. Impact of different volumes of boiling water on germination of *S. cepivora*

Sterilized soil was infested with *S. cepivora* by adding 100 Sclerotia per small bag and purred in soil. Boiling water (95-100 °C) at different volumes, i.e. 0.0, 0.2, 0.3, 0.4, and 0.5 L/kg soil, were used as soil treatments to investigate their effect on Sclerotia germination of *S. cepivora*. One day following treatment, small bags containing Sclerotia was removed from the soil, and the percentage of germinated Sclerotia was recorded as mentioned before.

2.4.2. Impact of hot water temperatures (at rate 0.5 L / kg soil) on germination of *S. cepivora*

As previously stated, the soil was infested with *S. cepivora*. Various hot water temperatures at rates of 0.5 L/kg soil, i.e. 30.0, 70.0, 80.0, 90.0, and 100.0 °C, were used as soil treatments to examine their effect on *S. cepivora* germination. One day following treatment, small bags containing Sclerotia was retrieved from the soil, and the percentage of germinated Sclerotia was calculated as previously described.

2.4.3. Impact of hot water treatments on white rot of onion plants

Temperatures of the soil were raised by either introducing varying amounts of boiling water (95-100 °C) or adding a constant volumes of hot water (0.5 L/ kg soil) different in its temperatures.

2.5. Fungus inoculum

Sclerotia of *S. cepivora* were extracted from infested soil according to method described by Coley-Smith *et al.*, (1987).

2.6. Soil infestation

On three consecutive days, sandy clay soil was sterilized at 120°C for one hour in autoclave. Plastic pots (35 cm in diameter, containing 5.0 kilogram of sterilized soil) were artificially infested with *S. cepivora* inoculum at a rate of 1000 Sclerocia per pot. Ten pots were utilized as replications for each treatment. Five onion seedlings (cv. Giza red) per pot were planted.

2.7. Impact of boiling water on white rot of onion plants in pot experiments

Boiling water (95- 100 °C) at different volumes *i.e.* 0.0, 0.2 ,0.3, 0.4 and 0.5 L / kg soil were tested against white rot disease of onion plants. After 24 h of soil treatment onion seedlings c.v. Giza red were planted at the rate of 5 seedlings / pot. and 10 pots were used as replicates.

2.8. Impact of hot water temperatures (at 0.5L /kg soil) on white rot of onion plants in pot experiments

Hot water at various degrees *i.e* 30.0, 70.0, 80.0, 90.0 and 100.0 ° C (at rate 0.5 L / kg soil) were applied against onion white rot disease in pot experiments. After 24 h of soil treatments, onion seedlings c.v. Giza red were planted at the rate of 5 seedlings / pot. and 10 pots were used as replicates.

2.9. Disease incidence

The percent of diseased plants were recorded post 100 days of planting

2.10. Disease severity

The severity scale is outlined below: 0 indicates healthy plants. 1 = Slightly severe (yellowing of the leaves, reduced root system), 2 = Moderately severe (yellowing and die-back of the leaves, severely decayed root system), 3 = Severe (complete yellowing of the plant, die-back of the leaves, semi-watery soft rot of scales and roots), and 4 = Highly severe.

The disease severity was assessed using the formula published by Zewide *et al.* (2007): Disease severity (%) = [total of all ratings divided by (total number of plants x maximum score)] x100. At the conclusion of the study (100 days following transplantation).

2.11. Effect of hot water on some vegetative characters of onion plants

The previous treatments of boiling water or degrees of hot water were tested against some vegetative parameters of onion plants i.e. plant height, number of leaves per plant and plant biomass.

2.12. Statistical analysis

The Tukey test was used to compare means numerous times (Neler *et al.*, 1985).

3. Results

3.1. Laboratory experiments

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

3.1.1.1. Effect on mycelia agar disks

Agar disks with *S. cepivora* mycelia were evaluated at various temperatures (25, 50, 52, 54, and 56 °C) and exposure times (5, 10, 15, and 50 minutes). Data in Table (1) shows that the lethal temperatures for *S. cepivora* were 54.0 and 56.0 degrees Celsius for 15 and 5.0 minutes, respectively.

3.1.1.2. Effect on sclerotia viability

The results in Table (2) show that the lethal temperatures of hot water to Sclerotia of *S. cepivora* were 60.0 and 65.0 °C for 15 and 5.0 min, respectively.

3.2. Pot experiments

3.2.1. Impact of hot water treatments on onion white rot in pot experiments

In pot studies, various volumes of boiling water (100 °C) soil treatments and varying degrees of hot water at a rate of 0.5 L/kg soil were investigated to see how they affected soil temperatures, Sclerotia viability, and white rot disease in onion plants.

3.3. Effect of hot water on soil temperatures

Data in Figures 1 and 2 show that all tested of hot water volumes resulting in increasing soil temperature. Increasing soil temperature was achieved with hot water at rates of 0.4 and 0.5 L per kg soil, as increasing soil temperatures to 80.5 and 85.0 °C, respectively. The largest rise in soil temperatures was measured at 90.0 and 100.0 °C at a rate of 0.5 L/kg soil, raising soil temperatures to 73.0 and 84.0 °C respectively.

3.4. Effect of hot water on Sclerotia germination of *S. cepivora*

Data in Fig (3 and 4) reveal that all volumes of boiling water or degrees of hot water significantly reduced the percent of sclerotia germination. Complete inhibition of sclerotia germination was achieved with boiling water at 0.4 and 0.5 L/ kg soil and the degrees of hot water at 90 and 100.0 °C.

Table 1: Viability of mycelial agar disks of *S. cepivora* fungus in response to hot water treatments.

Hot water °C	Viability of <i>S. cepivora</i>			
	Exposure time (minutes)			
	5	10	15	20
25	Yes	Yes	Yes	Yes
50	Yes	Yes	Yes	Yes
52	Yes	Yes	Yes	Yes
54	Yes	Yes	No	No
56	No	No	No	No

Yes : Indicate growth , No: Indicate no growth

Table 2: Viability of Sclerotia of *S. cepivora* fungus in response to hot water treatments.

Hot water °C	Viability of Sclerotia %			
	Exposure time (minutes)			
	5	10	15	20
25	Yes	Yes	Yes	Yes
50	Yes	Yes	Yes	Yes
55	Yes	Yes	Yes	Yes
60	Yes	Yes	No	No
65	No	No	No	No

Yes: Indicate growth, No: Indicate no growth

3.5. Impact of hot water on white rot disease

The results in Tables (3 and 4) show that all tested volumes of boiling water or degrees of hot water considerably reduced the percentage of white rot disease in onion plants. Disease incidence and severity were completely suppressed by boiling water at 0.5 L/kg soil and hot water at 100.0 °C. The greatest reduction was achieved with hot water at 90 °C and boiling water at 0.4 L/kg soil, which reduced disease incidence and severity by 85.0 & 62.5 and 70.0 & 62.5%, respectively. Other treatments proved less effective.

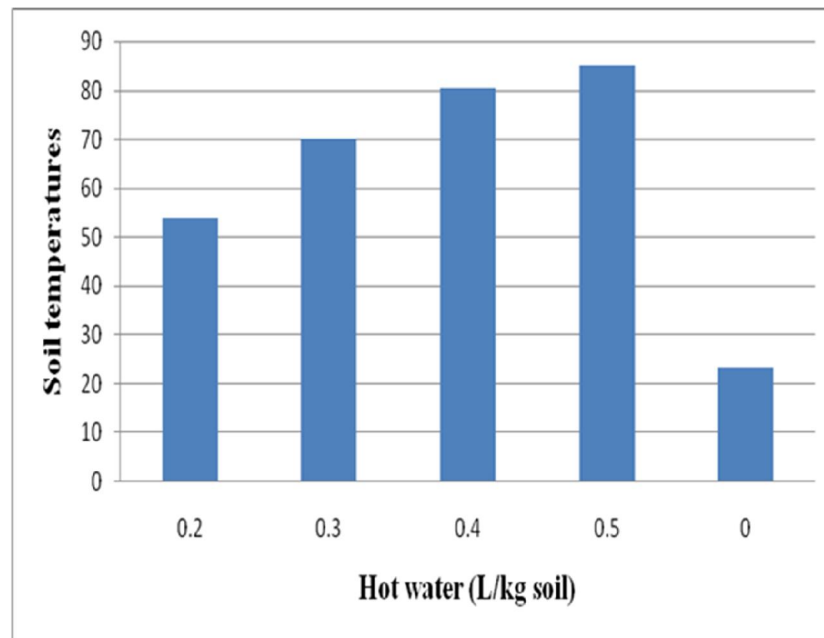


Fig. 1: Average minimum soil temperature in response to different volumes of boiling water.

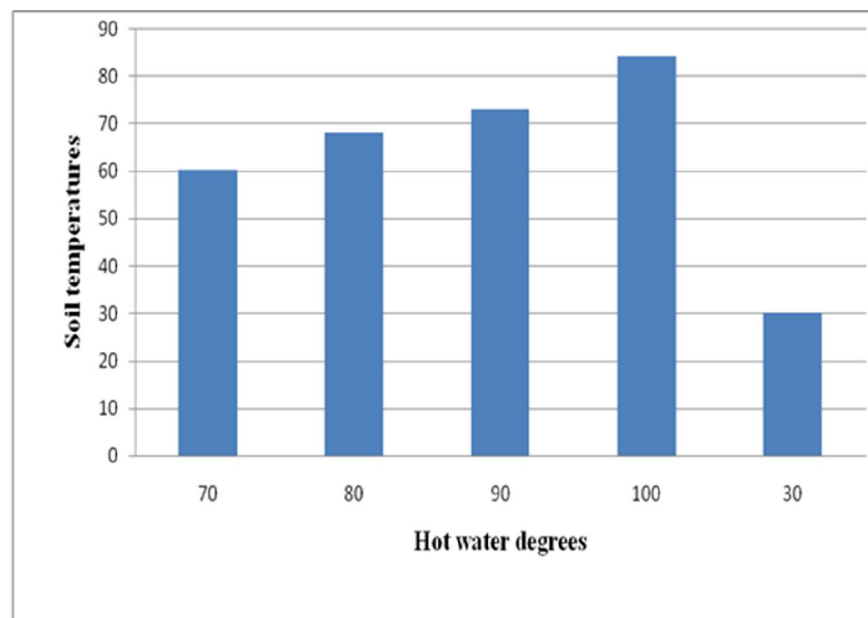


Fig. 2: Average soil temperatures as affected with different degrees of hot water temperatures (at rate 0.5 L / kg soil).

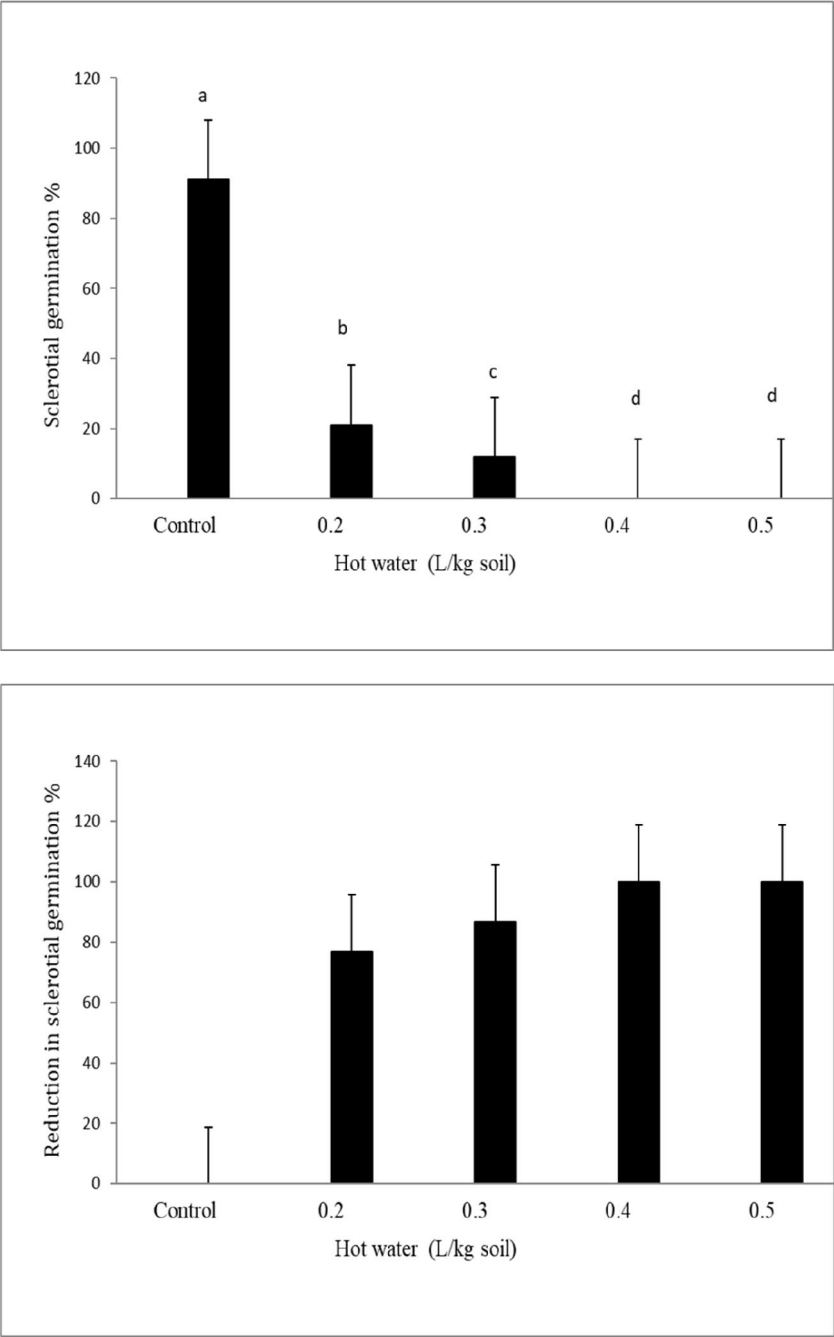


Fig. 3: Sclerotia germination and reduction % as affected with different volumes of boiling water.

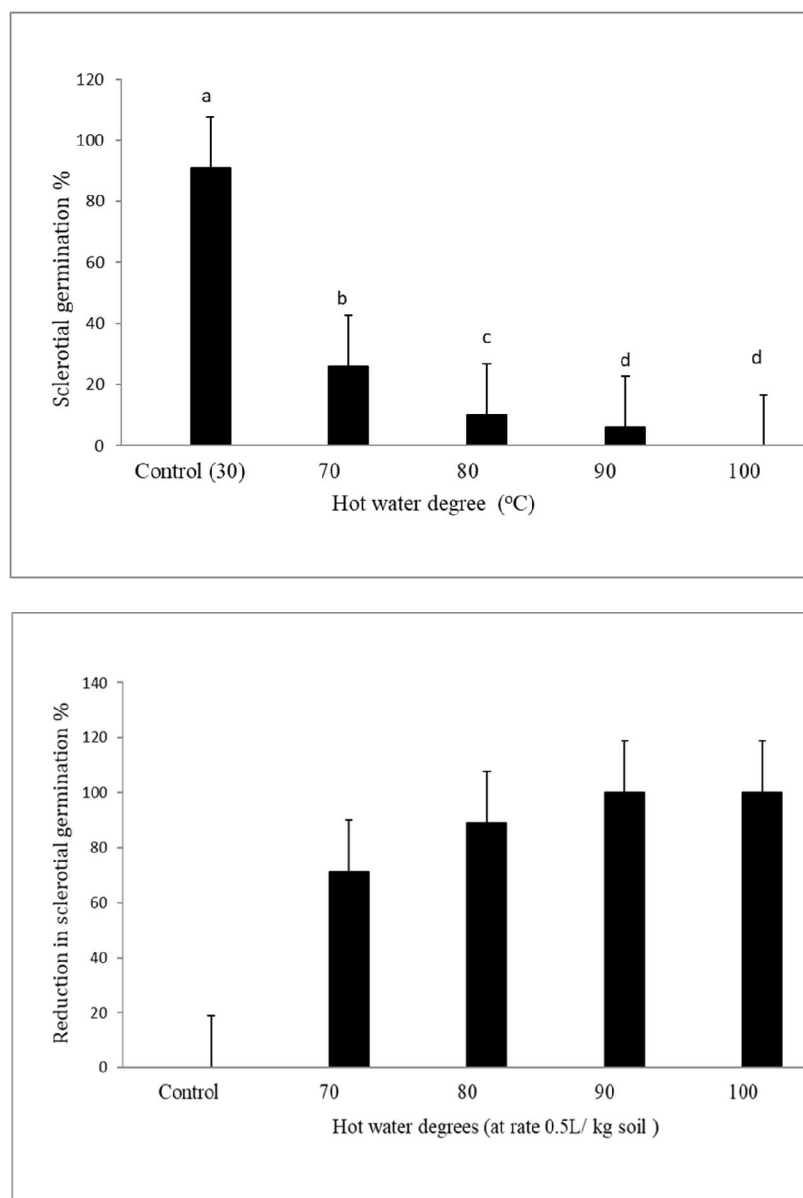


Fig. 4: Sclerotial germination as affected with different degrees of hot water temperatures (at rate 0.5 L / kg soil)

Table 3: Impact of different volumes of hot water (95- 100 °C) treatments on white rot disease

Hot water soil treatment (95-100 °C)	White rot disease			
	Disease incidence	Reduction %	Disease severity	Reduction %
0.2	33.3 b	58.4	40.0 b	50.0
0.3	24.0 c	70.0	30.0 b	62.5
0.4	20.0 c	85.0	20.0 c	85.0
0.5	0.0 d	100.0	0.0 c	100.0
Control (non – infested soil	0.0 d	100.0	0.0 c	100.0
Control (Infested) soil)	80.0 a	0.0	80.0 a	0.0

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

Table 4: Impact of various hot water temperatures (at rate 0.5 L/kg soil) on white rot of onion plants

Hot water (°C) (0.5L/kg soil)	White rot disease			
	Disease incidence	Reduction %	Disease severity	Reduction %
70	60.0 b	25.0	5.0 b	37.5
80	30.0 c	62.5	4.0 bc	50.0
90	20.0 d	85.0	30.0 c	62.5
100	0.0 e	100.0	0.0 d	100.0
Control (non- infested soil)	0.0 e	100.0	0.0 d	100.0
Control(Infested) soil)	80.0 a	0.0	80.0 a	0.0

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

3.6. Impact of hot water on some vegetative characters of onion plants

Data in Tables (5 & 6) show that all volumes of boiling water or degrees of hot water significantly increased all tested vegetative characters of onion plants. Boiling water at 0.4 and 0.5 L/kg soil and hot water at 90 and 100.0 °C recorded the highest increase in Plant height, number of leaves per plant and Plant biomass. Other treatments proved less effective.

Table 5: Influence of different volumes of hot water treatments (95- 100 °C) on some vegetative characters of onion plants.

Hot water soil treatment (95-100 °C)	Vegetative characters of onion plants					
	Exp. 1			Exp.2		
	Plant height (cm)	No. of leaves/plant	Plant biomass (g)	Plant height (cm)	No. of leaves/plant	Plant biomass (g)
0.2	49.0b	5.3b	27.5c	48.0b	5.2b	28.0c
0.3	51.2b	5.3b	32.0b	50.0b	5.2b	31.2b
0.4	58.4a	6.0a	40.0a	57.0a	6.0a	41.0a
0.5	59.0 a	6.1a	41.0a	57.5a	6.0a	42.0a
Control (infested soil)	45.0c	5.0c	23.0d	44.5c	4.9c	23.2d

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

Table 6: Influence of different hot water treatments (at rate 0.5 L/kg soil) on some vegetative characters of onion plants.

Hot water temperatures (0.5L/kg soil)	Vegetative characters of onion plants					
	Exp. 1			Exp.2		
	Plant height (cm)	No. of leaves/plant	Plant Biomass (g)	Plant height (cm)	No. of leaves/plant	Plant Biomass (g)
70	51.0c	5.4b	28.2c	52.0c	5.3c	27.5c
80	54.0b	5.6b	32.0b	55.0b	5.5b	33.0b
90	60.0a	5.9a	41.0a	61.3a	6.2a	42.0a
100	60.0a	6.0a	42.0a	61.0a	6.1a	44.0a
Control (infested soil)	45.0d	5.1c	23.0d	44.5d	4.9d	23.2d

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

4. Discussion

The pathogen *Stromatinia cepivora* (Berk.) Whetzel causes onion white rot by destroying the roots, killing the plant, and producing resting bodies that can remain in the soil for many years (Jones, 2010). Controlling this disease with chemical fungicides has lingering adverse effects on humans and the environment.

Ogawara *et al.* (2006) and Kita (2007) reported on the use of hot water treatments to sterilize soil and control many soil-borne diseases. The results of the current investigation demonstrated that the lethal temperature for *S. cepivora* mycelium were 54.0 and 56.0 degrees Celsius for 15 and 5.0 minutes,

respectively. While the lethal temperatures for Sclerotia of *S. cepivora* were 60.0 and 65.0 degrees Celsius for 15 and 5.0 minutes, respectively.

In this respect, Sundarum (1986) observed that organisms' incapacity to endure high temperatures are associated with an upper limit in membrane fluidity, whereby membrane instability could be caused by a failure in membrane function. The gradual deactivation of respiration enzymes is another cause of microbe thermal (Brock, 1978; Sundarum, 1986). These are direct effects accounting for a large amount of the decline in soil-borne microbe and weed seed populations. However, some of the advantages of hot water are indirect. For example, heat-stressed plant pathogen cells are many orders of magnitude more sensitive to soil fumigants, harmful microbes that can withstand high soil temperatures and potential alterations in the gas environment brought on by soil solarization. Soil heat treatment affect its structure, the soluble mineral compounds available for the growth of microorganisms and plants, as well as the account of soil-borne microbes (Chen, and Katan, 1980, Stapleton, and DeVay, 1984 and Stapleton, *et al.*, 1985).

The inoculum density is impacted by these modifications, aggressiveness, and survival of plant pathogens. Other soil-borne microorganism populations change during solarization, which affect soil disease suppression and the improved plant growth (Katan, 1987; Stapleton and DeVay, 1984; Stapleton *et al.*, 1985).

Spraying hot water (95–100°C) onto the soil surface raises the temperature to a point where plant diseases, pests, and weed seeds can no longer survive (Kita *et al.*, 2003; Fujinaga *et al.*, 2005; and Ogawara *et al.*, 2006).

In the current investigation, under pot trials, results indicated that complete inhibition of sclerotia germination was achieved by boiling water at 0.4 and 0.5 L/kg soil and degrees of hot water at 90 and 100.0°C. Furthermore, white rot disease was completely suppressed with boiling water at 0.4 and 0.5 L/kg soil, as well as degrees of hot water at 100.0 oC. The greatest reduction was achieved with hot water at 90 oC and boiling water at 0.3 L/kg soil. Other treatments proved less effective. In this regards,

Mahdy *et al.* (2011) reported that in the laboratory, agar disks of root rot fungi were exposed to a range of hot water temperatures and durations. The results showed that growth suspension was more sensitive to temperature and exposure time than mycelia-containing agar disks. Boiling water at 0.4 and 0.5 l/kg soil, as well as hot water at 90.0 and 100 °C at 0.5 l/kg soil, resulted in a complete suppression of the total count of pathogenic fungi. In terms of disease incidence, boiling water at rates of 0.4 and 0.5 l/kg soil and hot water at 90.0 and 100 °C (0.5 L/kg soil) inhibiter root rot more than 88.4 and 92.9% respectively.

Soil sterilization with hot water treatments has been used to control numerous soil-borne diseases(Kuniyasa *et al.*, 1993 ; Iwamoto *et al.*, 2000 and El-Mohamedy, and Abd- El-Kareem, 2013; Iwamoto *et al.*, 2005 and Ogawara, *et al.*, 2006).

Soil sterilization with hot water treatments has been documented to control numerous soil-borne diseasesIwamoto *et al.*, (2000) ; Nishi, (2005), Ogawara, *et al.*, (2006) ; Kita, (2007) and Mahdy *et al.*, (2011 and 2012). In this concern Uematsu *et al.* (2003) investigated the effect of hot water treatment on the development of Verticillium wilt in tomato plants in a commercial greenhouse. A volume of 200L/m² hot water boiled at 95°C was sprayed onto the soil surface. At the end of the harvest, the ultimate disease incidence was assessed. Disease incidence has been drastically reduced by hot water treatment, from 99.4 to 16.0%.

Moreover, Nishi (2005) revealed that hot water soil in vegetable cultivation under structure is a method of controlling microorganisms by heat with higher soil temperature by injecting hot water at 80 to 95 degrees Celsius into the field. This approach is useful for pest control of mold fungus, bacteria, nematodes, soil noxious insects, and weeds, among others. This approach has a long usage time with stability, and it is suitable for warm places throughout the year as well as cold areas, except during exceptionally cold periods. Crop growth is encouraged by the employment of this approach, which results in good rootlet growth and increased root hair quantity, implying an improvement in yield. The number of farmhouses that adopt this technology is continuously increasing.

Saied-Neהל, (2011) reported that cloth bags were artificially infested with pathogenic fungi i.e. *R. solani*, *F. solani*, *S. rolfsii* and *P. ultimum* were buried at three depths of soil surface i.e. 1-10, 11-20, and 21- 30 cm before soil treatments . The results showed that the Buried pipes system reduced the total count of all tested fungi at all depths, but the Sprinklers system was active at all depths except 21-30 cm below the soil surface with *F. solani* and *P. ultimum* fungi. Actinomycetes showed higher heat

tolerance than that of fungal plant pathogens, while, bacteria showed moderated tolerance to hot water and soil solarization. Also, under commercial greenhouse conditions, results showed that hot water as a Buried pipes system provided complete protection against root rot disease for 2.0 hours when applied once or twice, as well as hot water as a Sprinklers system at a rate of 40 L/m² and Basamid when applied twice. Furthermore, in contrast to steam sterilisation, hot water treatment is simpler to utilise and isn't limited to summer use like solar heat sterilisation is. This method is regarded as an environmentally benign methyl bromide substitute that may be extensively utilised in crop production because the damp heat generated by the hot water does not destroy all living organisms.

We discovered considerable growth-promoting advantages in any crop as a result of the hot water treatment, most likely due to the noticeable increase in chemical and physical soil qualities caused by the enormous volume of hot water washout. For more than ten years, some pioneering greenhouse tomato and rose producers have used this strategy. The precise volume of water required to treat most fields is dictated by soil type, ambient soil temperature, soil depth to be treated, and treatment area (e.g., whole field or seedling beds) (Noling, 1995; Kita, 2007).

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