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Soil solarization for controlling soil borne fungi of Tomato (*Lycopersicon esculentum* Mill.) plants. *1: Effect of hot water treatment and exposures time on Viability of tomato soil borne pathogenic fungi*

Riad S.R. El–Mohamedy and Farid Abd- El-Kareem

Plant Pathology Department, National Research Center, Dokki, Giza, Egypt

ABSTRACT

Viability of tomato soilborne Pathogenic fungi *i.e, F. oxysporum f. sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici*(FORL), *F.solani, R. solani* and *S. rolfsii* were tested against different temperatures and exposure times in digital water path under laboratory conditions. The lethal temperatures to *R. solani*, *F. solani* and *S. rolfsii when* were exposed to temperatures for one minutes as agar disks and/or growth suspension were 54.0, 58.0,56^{o}C and 52.0, 56.0 or 54.0^{o}C respectively. Meanwhile, the lethal temperatures to *F. oxysporum* f. sp. *lycopersici* (FOL)and *F. oxysporum* f.sp. *radicis lycopersici*(FORL)were 56 C and 54^{o}C when were exposed to temperatures for one minutes as agar disks or growth suspension respectively. Chlamydospores are more resistant to high temperatures as they were killed at 62 and 60^{o}Cfor *F. solani* and FOL or FORL respectively.While Sclerotia were killed at 58.0 C for R. *solani* and *S. rolfsii* when exposed to hot water for one minute. Sub lethal temperatures reduced the linear growth of ***F***. *solani*, *F. oxysporum f.sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici* (FORL) more than 50% and significantly reduced all resting stage production of ***F***. *solani* ,*F.oxysporum f.sp. lycopersici*(FOL), *F. oxysporum f.sp. radicis lycopersici* (FORL), *R. solani* and *S. rolfsii*. Under greenhouse conditions results indicated that sublethal temperatures significantly reduced the root rot and wilt diseases for all tested fungi. It could be suggested that lethal or subletal temperatures resulted from soil solarization could be effectiveness in management tomato soilborn pathogenic fungi.

Key word: Tomato- soilborne fungi -lethal temperatures-heat treatment.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) plants are the one of most important vegetable crops in Egypt and other countries. *Rhizoctonia solani, Fusarium solani, Fusarium oxysporum f.sp. lycopersici* (FOL), *Fusarium oxysporum f.sp. radicis lycopersici*(FORL) ,and *Sclerotium rolfsii* are the most damaging soil-borne diseases of tomato and becoming more common in greenhouse tomato production. The disease occurs in both the greenhouse and the field on tomato worldwide and causes significant losses in tomato production (Gotta and Tameitti , 1990 ; Dwivedi 1991; Rattink ,1993; McGovern *et al*., 1998; Kuckareck *et al*., 2000).

Soil solarization was carried out as transparent polyethylene plastic placed on moist soil during the hot summer months increases soil temperatures to levels lethal to many soil-borne plant pathogens, weeds and nematodes (Primo and Cartia, 2001; Abd-El-Kareem, *et al*., 2004; Culman, *et al.*, 2006, Farag and Fotouh, 2010 and Saied, 2011). Solarization also effectively controls weeds, increases soil nutrient availability (Schreiner, *et al*., 2001) and increases populations of known beneficial bacteria and fungi (Kaewruang, *et al*., 1989; Gamliel and Katan, 1991 and Abdel-Kader and Ashour, 1999). Heating the surface soil over a period of several weeks helps to control pathogenic fungi and lead to reduction of plant diseases caused by soil borne fungi (Abd-El-Kareem, *et al*., 2004; Culman, *et al*, 2006 and Farag and Fotouh, 2010). The present work was designed to study the effect of hot water temperatures and exposures time on viability of tomato soil borne fungi under laboratory and green house conditions.

Materials And Methods

Laboratory experiments:

Effect of hot water treatment on viability of tomato soilborne fungi:

Viability of agar disks with mycelia, growth suspension and resting stages of *Rhizoctonia solani, Fusarium solani, Fusarium oxysporum f.sp. lycopersici* (FOL), *Fusarium oxysporum f.sp. radicis lycopersici* (FORL), and *Sclerotium rolfsii* was carried out according to the method described by Whiting, *et al.*, (2001). Growth agar disks, growth suspension and resting stage of tomato soil borne fungi were evaluated at different

Corresponding Author: Riad S.R. El–Mohamedy, Plant Pathology Department, National Research Center, Dokki, Giza, Egypt
E-mail: riadelmohamedy@yahoo.com

temperatures and exposure times using digital hot water bath (Neslab GP-300 Series Constant Temperature Bath, Union City, CA). Screw-cap glass vials, 20 cm long and 20 mm in diameter, containing 20.0 ml sterilized water were placed in water path at different temperatures.

Effect of hot-water treatment on mycelia agar disks viability of tomato soilborne fungi:

Disk of agar with mycelia and spores 6- mm diameter were cut from the grown edge of 10 days -old cultures of *R.Salami; F. solani ; S. rolfsii; F. oxysporum f.sp. lycopersici* (FOL); *F. oxysporum f.sp. radicis lycopersici* (FORL) growing on PDA medium. Agar disks were transferred to Screw-cap glass vials, 20 cm long and 20 mm in diameter, containing 20.0 ml sterilized water placed in water path at 25, 50, 52, 54, 56, and 58 ^{o}C for different exposures time *i. e*. 1, 10, 20, and 30 minutes. Treated growth agar disks were dried using sterilized filter paper and transferred into Petri-plates containing PDA medium. Five Screw-cap glass vials , and 3 disks per each were used for each treatment .Viability of mycelia from agar disk that had been subjected to previous temperatures with different exposure times was assessed by planting treated disks on PDA medium and incubated at 25 ºC for 5 days .Disks that showing growth or non- growth were recorded.

Effect of hot-water treatment on growth suspension viability of tomato soilborne fungi:

Plates with growing colonies of *R. solan; F. solani; S. rolfsii*; *F. oxysporum f.sp. lycopersici* (FOL) and *F. oxysporum f.sp. radicis lycopersici* (FORL) grown on PDA medium were flooded with 10 ml of sterile water and mycelia or spores were released using a sterile inoculation loop. The growth suspension (spore or mycelia) were blended in blender under sterilized conditions. The number of spores or mycelial fragments in the stock suspension was counted with a haemocytometer slide and adjusted to 10^6 cfu or mycelial fragments / ml . One ml of growth suspensions was added to Screw-cap glass vials, 20 cm long and 20 mm in diameter, containing 20.0 ml sterilized water placed in water path at 25, 50, 52, 54, 56, and 58 ^{o}C, for different exposures times *i. e*. 1, 10, 20, and 30 minutes. One ml of treated suspension was transferred into Petri plates (9 cm diameter) and sterilized PDA medium before its solidification disbanded in Petri- plates which containing treated growth suspensions . Plates were incubated at 25°C for 5 days. Plates showing growth or non- growth were recorded.

Effect of hot-water treatment on resting stage viability of tomato soil borne fungi:

Different hot water temperatures *i.e.* 25, 54, 56, 58, 60 and, 62 ^{o}C, for exposures time *i. e*, 1, 5, 10, 15, 20, 25 and 30 minutes were tested to study their effect on the resting stage germination of *F. solani*, *F. oxysporum f.sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici* (FORL), *R. solani* and *S. rolfsii* under laboratory conditions.

Effect on sclerotia of S. rolfsii:

Sclerotia of S. *rolfsii* were harvested and surface disinfected with Ethanol alcohol (70 %) for 3 sec, then washed with sterilized water several times. Sclerotia were transferred to glass vials in digital water path at different temperatures and exposure times as mentioned before. Treated sclerotia were dried using sterilized filter paper and transferred to Petri-plates containing PDA medium. Determination of sclerotia germination was carried out according to the method described by Edmunds and Gleason, (2003).Ten sclerotia were distributed evenly on the surface of each Petri plate. The plates were incubated at 25C for 5 days. Sclerotia were considered to have germinated if the white, mycelium characteristic of S. *rolfsii* was presented after 5 days. Percentage of sclerotia germination was recorded.

Effect on sclerotia of R. solani:

Sclerotia of *R. solani* were harvest and surface disinfected with Ethanol alcohol (70 %) for 3 sec, then washed with sterilized water several times. Sclerotia were transferred to glass vials in digital water path at different temperatures and exposure times as mentioned before. Treated and un treated sclerotia were dried on sterilized filter paper. Determination of sclerotia germination was carried out according to the method described by Demirci *et al*., (2009). The sclerotia were placed on the Petri plates, and incubated at 20 ^{o}C in a sterile humidity chamber (100% rh). After 30 days, the viability of *R. solani* sclerotia was estimated by placing them on PDA medium for 5 days at 25 ^{o}C. Percentage of sclerotia germination was recorded.

Effect on chlamydospores of Fusarium spp:

Chlamydospores suspension was prepared by culturing F, *salami, F. oxysporum f.sp. lycopersici* (FOL) and *F. oxysporum f.sp. radicis lycopersici*(FORL) on Petri-plates containing water agar medium for 20 days at

25°C. Colony forming units (cfu) containing Chlamydospores were released in sterilized water using a needle and 1 ml of suspension was transferred to Screw-cap glass vials, 20 cm long and 20 mm in diameter, containing 20.0 ml sterilized water placed in water path at different temperatures and exposure times as mentioned before. One ml of treated chlamydospores suspension was transferred to test tube containing sterilized broth PD medium. Test tubes were incubated at 25°C for 24 h. One ml of treated colony forming units (cfu) containing chlamydospores was examined microscopy and percent of chlamydospores germination was calculated.

Effect of sublethal temperatures on linear growth of tomato soilborne fungi:

Agar disks with mycelia of *F. solani*, *F. oxysporum f.sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici* (FORL), *R. solani* and *S. rolfsii* were exposed to sublethal temperatures *i.e.* 56.0, 54.0, 54.0, 52 and 54.0 respectively, for 10 minutes (as mentioned before). Optimum temperatures (25.0 - 27 ^{o}C) for all tested fungi served as control. Petri plates (9 cm – diameter) containing PDA medium were individually inoculated at the center with treated growth agar disks. Five plates were used as replicates for each particular treatment. Inoculated plates were incubated at 25 ± 2 °C. The average linear growth of fungi was calculated every two days.

Effect of sublethal temperatures on resting stage production of tomato soilborne fungi:

Agar disks with mycelia of *F. solani*, *F. oxysporum f.sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici* (FORL), *R. solani* and *S. rolfsii* were exposed to sublethal temperatures *i.e.* 56.0, 54.0, 54.0, 52 and 54.0 respectively for 10 minute (as mentioned before). Optimum temperatures (25.0 - 27 ^{o}C) for all tested fungi served as control. Petri plates (9 cm – diameter) containing PDA medium were individually inoculated at the center with treated growth agar disks. Five plates were used as replicates for each particular treatment. Inoculated plates were incubated at 25 ± 2 °C for 30 days . Production of chlamydospores or sclerotia / cm^2 was estimated.

Pot experiments:

Effect of sublethal temperature of hot water treatments on pathogenic ability of tomato soil-borne fungi under greenhouse conditions:

Agar disks with mycelia of **F**. *salami*, *F. oxysporum f.sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici* (FORL), *R. solani* and *S. rolfsii* were exposed to sublethal temperatures *i.e.* 56.0, 54.0, 54.0, 52 and 54.0 respectively for 10 minute (as mentioned before). Optimum temperatures (25.0 ^{o}C) for all tested fungi served as control. Growth of treated fungi were maintained on PDA medium *Inoculum preparation, and soil infestation*

Inocula of *R. solani*, *F. solani*, *S. rolfsii* and *P. ultimum* were prepared by culturing each fungus on 50.0 ml potato dextrose broth (PDB) medium in 250 ml Erlenmeyer flasks for 15 days at 25° - 27 ^{o}C. and fungal inocula were prepared as follows:

Inoculum of *F. solani* was prepared from the growing upper solid layers which washed and blended in sterilized water .Colonies forming units (cfu) were adjusted to 10 ^{6} cfu / ml using haemocytometers slide. Soil infestation was carried out at rate of 50 ml (10 ^{6} cfu / ml) / kg soil (Elad and Baker, 1985).

Inoculum of *S. rolfsii* and *R. solani* was prepared from the growing upper solid layers which washed and air-dried with sterilized filter paper layers. The air-dry mycelium was blended in distilled water to obtain inocula pieces of 1-2 mm in diameter. Soil infestation was carried out at rate of 2.0 g dry mycelium / kg soil, (Al-Mahareeq, 2005).

Inoculum of *P. ultimum* was prepared from the growing upper solid layers which washed and blended in distilled water. Propagules were adjusted to 10^{6} / ml using haemocytometers slide. Soil infestation was carried out at rate of 50 ml (10^{6} Propagules/ ml) / kg soil (Lu *et al*., 2004).

Soil infestation:

Sandy -loamy soil was autoclaved at 120°C for 1 h on three successive days. Plastic pots (30 cm diameter, 5.0 kg soil) containing sterilized sandy-loamy soil were artificially infested individual with the inoculm of each fungus as mentioned before. Eight pots were used as replicates for each treatment as well as check treatment (un- infested soil). Disinfected cucumber seeds, c.v. Beit Alpha, were sown at the rate of 8 seeds / pot. Root rot disease was recorded as percentages of diseased plants after 20 and 40 days of sowing date.

Statistical analysis:

Tukey test for multiple comparison among means was utilized (Neler, *et al.*,1985).

Results:

Effect on mycelia agar disks and growth suspension:

Viability of agar disks with mycelia and growth suspension of *R. solani, F. solani, F. oxysporum f. sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici*(FORL) ,and *S. rolfsii* were tested against different temperatures *i.e.* 25, 50, 52, 54, 56, and 58 ^{o}C and exposure times *i. e*, 1, 10, 20, and 30 minutes in digital water path. Results in Table (1 and 2) indicate that growth (spores or mycelial) suspension more sensitive than disks of agar to high temperatures and exposure times . When exposures times increased the lethal temperatures of hot water decreased for all tested fungi. The lethal temperatures to *R. solani , F. solani* and *S. rolfsii* were 54.0 , 58.0 or 56 ^{o}C and 52.0 , 56.0 or 54.0 ^{o}C when were exposed to temperatures for one minutes as agar disks or growth suspension respectively .Meanwhile, the lethal temperatures to *F. oxysporum* f. sp. *lycopersici* (FOL), *F. oxysporum* f.sp. *radicis lycopersici*(FORL) were 56 ^{o}C and 54 ^{o}C when were exposed to temperatures for one minutes as agar disks or growth suspension respectively

Table 1: Viability of mycelia agar disks of tomato soil borne fungi as affected with hot water temperatures and exposure times.

Hot water ^{o}C	Viability of tomato soil borne fungi																			
	Exposure time (minutes)																			
	F. solani				*S . rolfsii*				*R. solani*				*F. oxysporum f. sp. lycopersici*				*F. oxysporum* f.sp. *radicis lycopersici*			
	1	10	20	30	1	10	20	30	1	10	20	30	1	10	20	30	1	10	20	30
25	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
50	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
52	+	+	+	+	+	+	+	–	+	+	—	—	+	+	+	+	+	+	+	+
54	+	+	+	+	+	+	—	—	—	—	—	—	+	+	+	—	+	+	+	—
56	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
58	–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

1- (+) = Indicate growth (-) = Indicate no growth

Table 2: Viability of growth suspension of tomato soil borne fungi as affected with hot water temperatures and exposure times.

Hot water ^{o}C	Viability of tomato soil borne fungi																			
	Exposure time (minutes)																			
	F. solani				*S . rolfsii*				*R. solani*				*F. oxysporum f. sp. lycopersici*				*F. oxysporum* f.sp. *radicis lycopersici*			
	1	10	20	30	1	10	20	30	1	10	20	30	1	10	20	30	1	10	20	30
25	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
50	+	+	+	+	+	+	+	+	+	+	—	—	+	+	+	+	+	+	+	+
52	+	+	+	+	+	+	+	–	—	—	—	—	+	+	+	+	+	+	+	+
54	+	+	—	—	–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
56	–	—	—	—	–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
58	–	—	—	—	–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

1- (+) = Indicate growth (-) = Indicate no growth

Viability of resting stage of tomato soil borne fungi as affected with hot water temperatures and exposure times:

Different hot water temperatures *i.e*. 25, 54, 56, 58, 60 and 62 ^{o}C, for exposures time *i. e*, 1, 10, 20 and 30 minutes were tested to study their effect against resting stage germination of cucumber root rot fungi under laboratory conditions. Results in Table (3) indicate that when exposure times increased the lethal temperatures of hot water decreased for Chlamydospores and Sclerotia. Chlamydospores are more resistant to high temperatures as they were killed at 62 and 60 ^{o}C for *F. solani* and FOL or FORL respectively. While Sclerotia were killed at 58.0 ^{o}C for *R. solani* and *S. rolfsii* when exposed to hot water for one minutes.

Effect of sublethal temperatures on tomato soil borne fungi:

Effect of sublethal temperatures on linear growth and resting stage germination of *R. solani, F. solani, F. oxysporum f. sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici*(FORL), and *S. rolfsii* were tested.

Effect on linear growth of tomato soil borne fungi:

Agar disks with mycelia of *F. solani, F. oxysporum f.sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici*(FORL), *R. solani* and *S. rolfsii* were exposed to sublethal temperatures *i.e.* 56.0, 54.0, 54.0, 52 and 54.0 respectively, for 10 minutes to study their effect on linear growth of tomato root fungi. Results in Table

(4) indicate that sublethal temperatures significantly reduced the linear growth of all tested fungi. They reduced the linear growth of *F. solani*, *F. oxysporum f.sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici* (FORL) more than 50 % as compared with optimum temperatures.

Table 3: Viability of resting stage of tomato soil borne fungi as affected with hot water temperatures and

Hot water oC	Viability of tomato soil borne fungi																			
	Exposure time (minutes)																			
	Sclerotia								Chlamydospores											
	R. solani				*S . rolfsii*				*F. solani*				*F. oxysporum f. sp. lycopersici*				*F. oxysporum* f.sp. *radicis lycopersici*			
	1	10	20	30	1		20	30	1	10	20	30	1	10	20	30	1	10	20	30
25	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
52	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
54	+	+	–	–	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
56	+	+	–	–	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
58	–	–	–	–	–	–	–	–	+	+	+	+	+	+	–	–	+	+	–	–
60	–	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–
62	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

1- (+) = Indicate growth (-) = Indicate no growth

Table 4: Linear growth (mm) of tomato soil borne fungi exposed to sublethal temperatures.

Fungi	Temp. (^oC)	Linear growth (mm)				
		Days after incubated				
		2	4	6	8	10
F. oxysporum f. sp. lycopersici	Sublethal (54)	0.0	18	28	40	51
	Optimum (25)	25.0	51	64	78	90
F. oxysporum f. sp. lycopersici	Sublethal (54)	25	19	31	40	55
	Optimum (25)	26	50	64	84	90
F. solani	Sublethal (56)	0.0 b	21 b	30 b	41	54 b
	Optimum (25)	24 a	48 a	62 a	80 a	90 a
R. solani	Sublethal (52)	0.0 b	32 b	45 b	-	-
	Optimum (27)	45 a	75 a	90 a	-	-
S. rolfsii	Sublethal (54)	0.0 b	35 b	50 b	-	-
	Optimum (27)	40 a	70 a	90 a	-	-

Figures with the same letter are not significantly different , to compare between optimum and sublethal temperatures of each fungus (P = 0.05)

Effect on resting stage production:

The effect of exposure resting stage of *F. solani*, *F. oxysporum f.sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici*(FORL), *R. solani* and *S. rolfsii* to sublethal temperatures was shown in Table (5) Results show that sublethal temperatures significantly reduced all resting stage production. Exposure of resting stage of*F. solani*, *F. oxysporum f.sp. lycopersici* (FOL), *F. oxysporum f.sp. radicis lycopersici*(FORL) growth to sublethal temperature caused reduction in chlamydospores production by 61.0, 59.7 and 60.4 % respectively. Meanwhile exposure of resting stage of *S. rolfsii* and *R. solani* resulted in reducing Scleritia production by 57.1 and 50.0 % respectively.

Table 5: Average number of resting stage production of tomato soil borne fungi exposed to sublethal temperatures.

Resting stage	Temp. (^oC)	Resting stage production	
		Number /cm^2	Reduction %
Chlamydospores			
F. solani	Sublethal (56)	162 b	61.0
	Optimum (25)	415 a	—
F. oxysporum f. sp. lycopersici	Sublethal (54)	170 b	59.7
	Optimum (25)	422 a	—
F. oxysporum f. sp.radicis lycopersici	Sublethal (54)	165 b	60.4
	Optimum (25)	420 a	—
Sclerotia			
*S. rolfsi*i	Sublethal (54)	3.0 b	57.1
	Optimum (27)	7.0 a	—
R. solani	Sublethal (52)	2.0 b	50.0
	Optimum (27)	4.0 a	—

Figures with the same letter are not significantly different , to compare between optimum and sublethal temperatures (P = 0.05)

Effect of sublethal temperature on pathogenic ability of Tomato soil borne fungi under greenhouse conditions:

Results in Table (6) indicate that sublethal temperatures significantly reduced the root rot and wilt diseases for all tested fungi if compared with nrmal temperature (25 ^oC). It caused reduction in disease incidence more than 84.4 % for all tested fungi.

Table 6: Pathogenic ability of cucumber root rot fungi as affected with sublethal temperatures of hot water treatments.

fungi	Temp. °C	Tomato soil borne disease incidence %	
		Days after sowing	
		disease incidence	Reduction %
*F. solan*i	56.0*	23.0 b	55.8
	25.0**	52.0 a	—
R solani	52.0*	22.0 b	66.2
	25.0**	65.0 a	—
S. rolfsii	54.0*	20.0 b	71.4
	25.0**	70.0 a	—
F. oxysporum f. sp.radicis lycopersici	54.0*	24.0 b	54.4
	25.0**	53.0 a	—
F. oxysporum f. sp. lycopersici	54.0*	27.0 b	56.5
	25.0**	62.0 a	—

1- Figures with the same letter are not significantly different , to compare between optimum(**) and sublethal(*) temperatures of each fungus (P = 0.05)

Discussion:

Tomato soil borne pathogenic fungi consider the most damaging soil-borne diseases of tomato and becoming more common in greenhouse tomato production. Both diseases caused a significant threat to tomato transplant production and to both tomato field and greenhouse fruit production, wherever it accord (McGovern *et al*., 1998). Fusarium grown and root rot of tomato caused by Forl killed about 70-83% of tomato young plants causing rot and basal stem decay and eventually death (Kuckareck *et al*., 2000).

Soil solarization during summer months increases soil temperatures to lethal levels for many soil-borne plant pathogens, nematodes and weeds, (Primo and Cartia, 2001; Abd-El-Kareem *et al*., 2004; Culman, *et al*, 2006 and Farag and Fotouh, 2010). 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 (Brock, 1978 and Sundarum, 1986). These are direct effects of high soil temperatures and account for a major share of the reduction in populations of soil- borne micro-organisms and weed seeds. On the other hand, some effects of soil solarization or hot water are indirect. For example, 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. During heat treatments of soil, changes occur in the structure of soil, in soluble mineral substances available for plant and microbial growth, and in the populations of soil-borne micro-organisms (Chen, and Katan, 1980, Stapleton, and DeVay, 1984 and Stapleton, *et al.,* 1985). These changes affect the inoculum density of plant pathogens, and also their aggressiveness and survival. Changes in the populations of other soil - borne micro-organisms occur during and after solarization which may influence the disease suppressive of soil and also the increased plant growth response associated with heat treatments of soil (Katan, 1987, Stapleton, and DeVay. 1984 and Stapleton, *et al.,* 1985).

In the present study, under laboratory conditions, results indicated that the lethal temperatures to *R. solani , F. solani* and *S. rolfsii* were 54.0, 58.0 or 56 °C and 52.0, 56.0 or 54.0 °C when were exposed to temperatures for one minutes as agar disks or growth suspension respectively. Meanwhile, the lethal temperatures to *F. oxysporum* f. sp. *lycopersici* (FOL) and *F. oxysporum* f.sp. *radicis lycopersici* (FORL) were 56 °C and 54 °C when were exposed to temperatures for one minutes as agar disks or growth suspension respectively. Chlamydospores are more resistant to high temperatures as they were killed at 62 and 60 °C for *F. solani* and FOL or FORL respectively. While Sclerotia were killed at 58.0 °C for *R. solani* and *S. rolfsii* when exposed to hot water for one minutes. Sublethal temperatures significantly reduced the linear growth and reduced all resting stage production of all tested fungi.

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. In the present study results indicated that sublethal temperatures significantly reduced linear growth and resting stage production for all tested fungi . In this respect Pullman *et al.,* (1981) found that the effects of sublethal temperatures were pronounced when the fungi were exposed to temperatures of 37° to 39°C. Propagule was exposed to sublethal heating, the longer time was required for germination. Moreover, they suggested that the heat damage accumulates gradually to a point beyond which the propagule cannot recover. During sublethal heating, all living cells produce heat shock proteins (Freeman, *et al.,* 1989, Lindquist, 1986 and Plesofsky-vig, and Brambl, 1985). Heat shock proteins are associated with the acquisition of thermo tolerance or thermos/ability; however, fungi have a transient heat shock response that is short live, even if they are maintained at high temperature (Plesofsky-vig, and 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 *Sclerotium rolfsii* where the

rind of sclerotia becomes cracked resulting in increased leakage of various substances (Lifshitz, *et al.*, 1983). Weakened sclerotia are intensely colonized by *Trichoderma harzianum* and other micro-organisms (Greenberger *et al*., 1984 and Lifshitz, *et al*., 1983). Another example where soil solarization may affect the germination ability and aggressiveness of fungal propagules concerns *Rosellinia necratrix*. Post plant solarization of an apple orchard for the control of this pathogen provided evidence that the fungal propagules became highly vulnerable to colonization by *Trichoderma* species (Sztejnberg, *et al*., 1987).

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