Soil solarization and hot water for controlling cucumber root rot disease under commercial greenhouse conditions

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Abstract

Using of the hot water (95-100 ^{o}C) by Sprinklers system at rate 40 L/m^{2} and Buried pipes system for 2.0 h in addition to soil solarization were applied to control cucumber root rot disease which caused by *R. solani, F. solani S. rolfsii* and *P. ultimum* under commercial greenhouse conditions.
Results indicated that complete reduction in total count of all tested fungi was obtained with Buried pipes system with all depths and Sprinklers system with all depths, except that depth 21- 30 cm of soil surface with *F. solani* and *P. ultimum* fungi . Also, soil solarization was more effective in reducing the pathogen population. On the other hand, the complete protection against root rot disease was obtained with hot water as a Buried pipes system for 2.0 h when applied as one or two times and hot water applied as Sprinklers system at rate 40 L / m ^{2} the same results was obtained by Basamid when applied twice. Followed by hot water applied as Sprinklers system (one application) and soil solarization (two applications) it reduced the root rot disease by 85.9 and 90.7 %, respectively during the four growing seasons. As for cucumber yield the most effective treatments are hot water applied either Sprinklers or Buried pipes system which increased fruit yield by 116.4 and 123.4 % respectively (one application) and 125.5 and 134.5 % (two applications). Also, soil solarization increased the cucumber yield by 96.4 and 109.1% during four growing seasons when applied as one and two applications respectively. It could be suggested that hot water and soil solarization as soil treatments might be safely used commercially for controlling root rot disease of cucumber plants under greenhouse conditions.

Key words: Hot water, Soil solarization, Root rot disease, Cucumber plants, Greenhouse.

Introduction

Cucumber (*Cucumis sativus* L.) is one of the most important vegetable crops; the cultivated area was 70680 feddans in 2010 which yielded 530000 tons . It is grown in plastic houses in two main growing seasons *i.e.* autumn and winter in about 20769 greenhouses which yielded 137000 tons (Anonymous, 2010). Cucumber plants suffer from many fungal, bacterial and viral diseases that effect fruit yield. Root rot and root knot nematode are the most important diseases affecting the cucumber plants (Kiewnick *et al*., 2008, Abd- El -Kareem, 2009 and Morsy *et al.,* 2009) . Moreover, soil-borne pathogens, *Rhizoctonia solani* Khun ; *Pythuim ultimum* Trow *; Fusarium solani* (Mart.)App. & Wr., and *Sclerotium rolfsii* Sacc. can cause severe economic losses to field and greenhouse grown cucumber (Roberts *et al*., 2005; Haikal - Nahed, 2007 and JingHua, *et al.*, 2008). Using of the fungicidal treatments was the most commonly known means for controlling fungal disease in field and greenhouses (Washington and McGee, 2000 and Fravel *et al.*, 2005). Although this method has been very effective in controlling plant fungal disease, but some major problems threaten to limit the continued use of pesticides. Firstly some fungi have developed resistance to chemicals; secondly some pesticides are not readily biodegradable and tend to persist for years in environment. This leads to a third problem, the detrimental effects of chemicals on organisms other than target fungi (Brady, 1984). Because of these associated problems, researchers are now trying to use environmentally safe alternative methods for controlling soil-borne diseases. Application of hot water (95 to 100°C) onto soil surface raises the soil temperature up to the lethal level to the plant pathogens as well as pests and weed seeds (Kita *et al*., 2003 ; Fujinaga *et al.*, 2005 and Ogawara *et al.*, 2006). 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 and Farag – Eman and Fotouh 2010). The present work was designed to study the effect of hot water applied as Sprinklers system or Buried pipes system and soil solarization for controlling cucumber root rot disease under commercial greenhouse conditions.

Materials and Methods

Commercial greenhouse experiments were carried out, at Research and Production Station of National Research Centre at El-Noubareia, Behera governorate. Application of hot water treatments under commercial greenhouse conditions

Two systems, *i.e.* Sprinklers and Buried pipes were tested for application of hot water treatment under commercial greenhouse conditions as follow:

Sprinklers system

The Sprinklers system consists of 1- electric water heater (Universal Company Model 2009) for heating 200 L water (95- 100°C); 2- Water Motor (Kalbida Company 1.0 horse 2008) for pushing the hot water to Sprinklers; 3- Pipe , 3.0 m long , 2.25 cm diameter , and 10 cm above the soil surface . Pipe tolerant to heat which made of propylene has Sprinklers at the rate 4.0 Sprinklers / m. In this system the hot water (95 to 100 ^{o}C) was sprayed on the soil surface.

Buried pipes system (Closed hot water system)

The Buried pipes system consists of 1- electric water heater (Universal Company Model 2009) for heating 50 L water (95- 100°C) 2- water Motor (Kalbida Company 1.0 horse 2008) for pushing the hot water to buried pipes 3- Buried pipes , 5.0 m long , 2.25 cm diameter, 25.0 cm apart and 20.0 cm below the soil surface then covered with polyethylene tolerant to heat. In this system the hot water (95 to 100 ^{o}C) circulated in buried pipes for different times.

Testing of different volumes of hot water (95 to 100 ^{o}C) using Sprinklers system **on soil temperatures at different depths**

Different volumes of hot water (95 to 100 ^{o}C) *i.e.* 0.0, 20.0, 30.0 and 40.0 L / m^2 using Sprinklers system as mentioned before were tested to study their effect on soil temperatures at different deeps as mentioned above*i.e*. 1- 10 , 11 – 20 , 21- 30 and 31-40 cm of soil surface under commercial greenhouse conditions.

Testing of exposures time to hot water (95- 100 ^{o}C) using Buried pipes system on soil temperatures at different depths

Different exposure times *i.e*. 0.0 , 0.5 , 1.0, 1.5, 2.0 and 2.5 h to hot water (95 to 100 ^{o}C) using Buried pipes system as mentioned before were tested to study their effect on soil temperatures at different deeps as mentioned above.

Effects of hot water treatment and soil solarization on total count of cucumber root rot fungi.

Preparation of fungal inocula

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 as the upper solid layers that grew were 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 as the upper solid layers that grew were 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^{-1} soil, (**Al-Mahareeq , 2005).**

Inoculum of *P. ultimum* was prepared as the upper solid layers that grew were 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 infestations with root rot fungi

Certain weights of greenhouse soils (sandy- loam) were sterilized was autoclaved at 120°C for 1 h . Sterilized soil was artificially infested with individual inoculum of *R. solani, F. solani, S. rolfsii* and *P. ultimum* as mentioned before. Artificially infested soils were filled into cloth bags at the rate of 4.0 kg soil / bag.

Buried cloth bags into soil

Before soil treatments with hot water Sprinklers or Buried pipes systems and soil solarization cloths bags infested with pathogenic fungi were buried into the soil at three different levels down below the surface at depths of 1-10, 11-20, and 21- 30 cm at three spots of each plot, and each of the three depths was represented individually by one of the tested fungi.

Testing of hot water on population density of cucumber root rot fungi

Hot water (95-100 ^{o}C) using Sprinklers system was applied at rate 40 L / m ^{2} while, Buried pipes system was applied as hot water (95-100 ^{o}C) circulated, in buried pipes for 2.0 h were tested to study their effects on total count of root rot fungi .

Before soil treatments with hot water cloths bags infested with pathogenic fungi were buried into the soil as mentioned before. Seven days after hot water treatments the buried bags of each certain level in either Sprinklers **or** - Buried pipes were collected and transferred on to plastic pots (30 cm diameter) . Total count of pathogenic fungi either Sprinklers or Buried pipes as compared with their count before soil treatments was estimated.

Testing of soil solarization on population density of cucumber root rot fungi

Before soil mulching cloth bags infested with pathogenic fungi were buried into the soil as mentioned before. After removal the polyethylene sheets, the buried bags of each certain level in either solarized or un-solarized plots were collected and transferred on to plastic pots (30 cm diameter). Total count of pathogenic fungi in solarized and un-solarized soil as compared with their count before soil mulching was estimated.

Determination of total count of pathogenic fungi

Total count of pathogenic fungi was carried out according the methods described by Porras ***et al.*, (2007)**. The resulting colonies are then calculated as colonies per gram of dry soil and the reduction was calculated as follow:-

$$\text{Reduction }\% = \frac{\text{No. of colonies in control - No. of colonies in treatment}}{\text{No. of colonies in control}} \times 100$$

Evaluation of hot water and soil solarization to control cucumber root rot disease under commercial greenhouse conditions

The promising hot water treatments as Sprinklers, or Buried pipes systems , in addition to soil solarization , the pesticide Basamid (tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione) and un-treated soil were applied under commercial greenhouse conditions to study their effects on cucumber root rot disease in addition to fruit yield per m^2 .

Treatments: The following treatments were applied during two growing seasons:

1. Hot water (95-100 ^oC) using Sprinklers system at rate 40 L m^{-2}.
2. Hot water (95-100 ^oC) using Buried pipes system for 2.0 h .
3. Soil solarization for 8 weekly during July and August months.
4. Basamid applied at rate 50 g m^{-2} before sowing.
5. Un- treated soil (Control)

Each treatment was represented by 5 replicates and 40 plants for each replicate were used.

As for the second season, treated plots were divided into two groups, first, no additional treatments were added to them (one application), The second group was treated with the same treatments as in the first season (twice application).

Diseases assessment: The percentage of diseased plants caused by root rot disease was recorded up to three months of sowing.

Cucumber yield: Accumulated cucumber yield per treatment were recorded and average fruit yield (kg m^{-2}) were calculated for each treatment.

Statistical analysis

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

Results

Effect of different volumes of hot water (95 to 100^{o}C) using Sprinklers system on soil temperatures at different depths.

Different volumes of hot water (95 to 100 ^oC) *i.e*. 0.0 ,20.0, 30.0 and 40.0 L m^{-2} using Sprinklers system were tested to study their effect on soil temperatures at different depths *i.e*. 1- 10, 11 – 20, 21- 30 and 31-40 cm of soil surface under commercial greenhouse conditions. Results in Table 1 indicate that all tested volumes of hot water increased the soil temperatures. The highest increase was obtained with volume 40.0 L m^{-2} which increased the soil temperatures to 78.0, 72.0, 67.0 and 61.0 ^oC for depths 1- 10 , 11 – 20 , 21- 30 and 31-40 cm of soil surface, respectively. Hot water volume at 30.0 L m^{-2} raised the soil temperatures to 74.0, 69.0, 64.0 and 58.0 ^oC for depths 1- 10 , 11 – 20 , 21- 30 and 31-40 cm of soil surface, respectively. While, volume at 20.0 L m^{-2} was less effective.

Table 1. Soil temperatures at different depths under commercial greenhouse conditions as affected with different volumes of hot water (95-100 ^oC) using Sprinklers system.

Amount of hot water (L m^{-2})	Soil temperatures (^oC)			
	Soil depths (cm)			
	1-10	11- 20	21- 30	31- 40
	^{o}C	**^{o}C**	**^{o}C**	**^{o}C**
0.0	41.0	36.0	30.0	23.0
20.0	71.5	65.0	60.0	53.0
30.0	74.0	69.0	64.0	58.0
40.0	78.0	72.0	67.0	61.0

Effect of exposures time of hot water (95- 100 ^{o}C) using Buried pipes system on soil temperatures at different depths

Different exposure times *i.e* 0.0 , 0.5 , 1.0, 1.5, 2.0 and 2.5 h to hot water (95 to 100 ^oC) using Buried pipes system were tested to study their effect on soil temperatures at different depths *i.e*. 1- 10 , 11 – 20 , 21- 30 and 40.0 cm of soil surface. Results in Table 2 indicate that all tested exposure times resulted in increasing soil temperatures at different deeps. The highest increase was obtained with exposure times for 2.0 and 2.5h which increase the soil temperatures to 71.0 and 77.0, 75.0 and 80.0, 70.0 and 76.0 and 62.0 and 68.0 ^oC for 1- 10 , 11 – 20 , 21- 30 and 31-40 cm of soil surface, respectively. Moderate increase in soil temperatures was obtained with exposed soil to hot treatments for 1.5 and 1.0 h. Meanwhile, other exposure times showed less effect.

Effect of hot water treatments (Sprinklers and Buried pipes systems) on population density of cucumber root rot fungi

Hot water (95-100 ^oC) using Sprinklers system applied at rate 40 L m^{-2} and Buried pipes closed hot water system (95-100 ^oC) for 2.0 h. were tested to study their effects on total count of root rot fungi. Results in Table 3 indicate that both Sprinklers and Buried pipes system caused dramatically reduction in total count of all tested fungi. Complete reduction in total count of all tested fungi was obtained with Buried pipes system at all depths and Sprinklers system with all depths except that depth 21- 30 cm of soil surface with *F. solani* and *P. ultimum* fungi

Table 2. Soil temperatures at different depths under commercial greenhouse conditions as affected with different exposure times using Buried pipes system

Exposure times (h)	Soil temperatures (^oC)			
	Soil depths (cm)			
	1-10	11- 20	21- 30	31- 40
	^oC	^oC	^oC	^oC
0.0	40.5	36.5	31.0	24.0
0.5	49.0	50.5	48.0	43.0
1.0	56.0	59.0	53.0	50.5
1.5	63.0	67.5	61.0	59.0
2.0	71.0	75.0	70.0	62.0
2.5	77.0	80.0	76.0	68.0

Table 3. Reduction (%) in pathogenic fungi at three depths as affected with Sprinklers and Buried pipes systems under commercial greenhouse conditions.

Soil depths (cm)	Reduction (%) in cucumber root rot fungi							
	F. solani		*R. solani*		*S . rolfsii*		*P. ultimum*	
	Sprinklers	Buried pipes	Sprinklers	Buried pipes	Sprinklers	Buried pipes	Sprinklers	Buried pipes
1- 10	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
11- 20	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
21- 30	95.0	100.0	100.0	100.0	100.0	100.0	97.0	100.0

Effect of soil solarization on population density of cucumber root rot fungi

The population density of cucumber root rot pathogens was determined in artificially infested soil with *R. solani, F. solani S. rolfsii* and *P. ultimum* at three soil depths either in mulched or un-mulched soil.

Results in Table 4 indicate that fungal populations decreased in both mulched and un-mulched soils at the end of the experimental period. This effect the reduction was lesser with increasing soil depths. Complete reduction in total count of all tested fungi was observed in mulched soil at 1-10 and 11- 20 cm depths. As for the lower soil depth, 21-30 cm, the pathogen populations were reduced by 81.0, 100.0, 94.0 and 84.0 % for *F. solani, R. solani, S. rolfsii* and *P.ultimum,* respectively, when compared with the fungal population before soil mulching. The same trend was also noticed in fallow un-mulched soil at the three similar depths. It is interesting to note that the population density of *R. solani* and *S. rolfsii showed* the highest sensitivity to heat treatment followed by *F. solani* and *P. ultimum*. This observation is true at three depths in both mulched and un-mulched soil.

Table 4. Reduction (%) in pathogenic fungi at three depths as affected by mulched and un- mulched soil under commercial greenhouse conditions.

Treatments	Soil depths (cm)	Reduction in root rot fungi %			
		F. solani	*R. solani*	*S . rolfsii*	*P. ultimum*
Mulched soil	1- 10	100.0	100.0	100.0	100.0
	11- 20	100.0	100.0	100.0	100.0
	21- 30	81.0	100.0	94.0	84.0
Un Mulched soil	1- 10	38.0	44.0	48.0	40.0
	11- 20	22.0	32.0	35.0	20.0
	21- 30	8.0	21.0	22.0	11.0

Evaluation of hot water and soil solarization to control cucumber root diseases under commercial greenhouse conditions

Results in Table 5 indicate that all treatments applied as one or two applications significantly reduced the root rot disease of cucumber plants .Complete protection against root rot disease was obtained with hot water as a Buried pipes system for 2.0 h when applied as one or twice applications and hot water applied as Sprinklers system at rate 40 L m^{-2} as well as Basamid when applied twice. Followed by hot water applied at Sprinklers system (one application) and soil solarization (twice applications) which reduced the root rot disease by 85.9 and 90.7 %, respectively during four growing seasons . Moderate reduction was obtained with soil solarization (once application) which reduced the root rot by 76.7 %. Statistical analysis indicates that no significant differences between hot water applied either Sprinklers or Buried pipes system and the pesticide Basamid when applied twice except that Sprinklers system with root rots disease when applied one time

Table 5. Percentage of cucumber root rot disease as affected by hot water and soil solarization in comparison with pesticide under commercial greenhouse conditions during 2009 to 2011 growing seasons

Treatments	No. of application	Cucumber root rot disease %					
		Autumn growing seasons		Winter growing seasons		Average four experiments	
		2009 / 10	2010 / 11	2010	2011	Mean	Reduction %
Hot water (Sprinklers)	One	2.5c *	3.0 c	4.0 b	5.5 c	3.8 d	85.9
	Twice	—	0.0 d	—	00.0 e	0.0 e	100
Hot water (Buried pipes)	One	00.0 c	0.0 d	00.0	00.0 e	0.0 e	100
	Twice	—	0.0 d	—	00.0 e	0.0 e	100
Soil solarization	One	6.0 b	7.0 b	5.0 b	7.0 b	6.3 b	76.7
	Twice	—	3.0 c	—	2.0 d	2.5 d	90.7
Basamid	One	2.0 c	3.0 c	4.5 b	8.0 b	4.3 c	84.1
	Twice	—	0.0 d	—	00.0 e	0.0 e	100
Control		23.0 a	26.0 a	28.0 a	31.0 a	27.0 a	—

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

Effect of hot water and soil solarization on cucumber yield

Results in Table 6 indicate that all treatments significantly increased the cucumber yield during the four experiments. The most effective treatments were hot water applied by either Sprinklers or Buried pipes system which increased the fruit yield by 116.4 and 123.4 %, respectively (one application) and 125.5 and 134.5 % (two applications), respectively during four growing seasons. Followed by soil solarization which increased the cucumber yield by 96.4 and 109.1% during the four growing seasons when applied at once and twice applications, respectively.

Table 6. Influence of hot water and soil solarization in comparison with pesticide on cucumber yield under commercial greenhouse conditions during 2009 to 2011 growing seasons.

Treatments	No. of application	Cucumber yield (kg / m^2)					
		Autumn Growing seasons		Winter Growing seasons		Average yield during four experiments	
		2009/ 10	2010 / 11	2010	2011	Mean	Increase %
Hot water (Sprinklers)	Once	11.2 a*	11.5 ab	12.0 a	12.8 a	11.9	116.4
	Twice	—	11.7 a	—	13.0 a	12.4	125.5
Hot water (Buried pipes)	Once	11.5 a	12.0 a	12.4 a	13.2 a	12.3	123.4
	Twice	—	12.2 a	—	13.5 a	12.9	134.5
Soil solarization	Once	10.6 b	10.0 c	11.0 b	11.5 bc	10.8	96.4
	Twice	—	11.0 b	—	12.0 b	11.5	109.1
Basamid	Once	8.0 c	9.0 c	10.5 c	11.3 c	9.7	76.4
	Twice	—	9.5 c	—	11.5 bc	10.5	90.9
Control		5.8.0 d	5.6 e	5.4 d	5.2	5.5	—

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

Meanwhile, pesticide Basamid caused an increase in cucumber yield by 76.4 and 90.9 % when applied once and twice applications, respectively. It can be noticed that the effect of hot water applied either Sprinklers or Buried pipes system was similar to that pesticide Basamid for suppressition the cucumber root diseases but they significantly different in cucumber yield, which increased fruit yield ranged between (25.5 to 58.1 %) as compared with pesticide Basamid.

Discussion

Root rot was the most important diseases affecting cucumber plants specially in plastic houses. Many reports have been published in this concern by Kiewnick *et al*., (2008), Abd El Kareem(2009) and Morsy *et al.*, (2009). Controlling these diseases mainly depends on pesticide treatments. However, fungicidal applications cause hazards to human health and increase environmental pollution (Washington and McGee, 2000; Fravel *et al*., 2005). Therefore, alternative treatments for control of plant diseases are needed. The hot water treatment has recently been receiving special attention in Japan as the most promising Methyl bromide alternative (Kita *et al*., 2003). In present study results indicate there are two systems for application the hot water into soil *i.e.* Sprinkles system (95-100 ^{o}C) applied at rate 40 L / m ^{2} and Buried pipes system applied as hot water (95-100 ^{o}C) circulated, in buried pipes for 2.0 h both system Sprinkles and Buried pipes systems caused dramatically reduction in total count of all pathogenic fungi .

In this respect, Kita *et al*., (2003) reported when *Fusarium oxysporum* f.sp. *lycopersici* present within the 30cm depth, soil was exposed to the lethal temperature (55.0 ^{o}C) complete disinfestations was successfully achieved leading to the effective suppression of the wilt disease. Application of hot water (95 to 100°C) onto soil surface raise the soil temperature up to the lethal level to the plant pathogens as well as pests and weed seeds (Noling, 1995; Kita *et al*., 2003 ; Fujinaga *et al.*, 2005 and Ogawara *et al.*, 2006). Promising effects of hot water treatment of the soil-borne disease control have been confirmed in various crops such as tomato, melon, strawberry, spinach, rose, sweet pea and carnation (Uematsu *et al.*, 2003 and 2005).

Soil solarization during summer months increases soil temperatures to levels lethal to many soil-borne plant pathogens, weeds, nematodes, and some soil residing mites (Abd-El-Kareem *et al*., 2004; Shalaby and Mohamed, 2005 ; Arya, 2007 and Farag - Eman and Fotouh,2010). In present study, the population density of cucumber root rot pathogens were determined in artificially infested soil with *R. solani, F. solani S. rolfsii* and *Pythium sp.* at three soil deeps either in solarized or un-solarized soil. Results indicate that solarization was more effective in reducing the pathogens population. Complete reduction in total count of all tested fungi was observed in mulched soil at 1-10 and 11- 20 cm depths. These results are in agreement with those of Katan *et al.,* (1986) and Katan (1980) who demonstrated that the population of soil borne fungi, *i.e. Fusarium oxysporum*, *Rhizoctonia solani* and *Sclerotium rolfsii* reduced by 62 to 100 % in 5 to 25 cm depths in solarized soil. They added that the maximal temperatures in mulched soils reached 52, 49 and 42°C at 5, 15 and 25 cm soil depths, respectively. In the current study, under commercial greenhouse conditions results indicate that complete protection against root rot disease was obtained with hot water as Buried pipes system for 2.0 h when applied as one or twice applications and hot water applied as Sprinklers system at rate 40 L m^{-2} as well as Basamid when applied twice. As for cucumber yield the most effective treatments are hot water applied either Sprinklers or Buried pipes system which increased the fruit yield by 116.4 and 123.4 %, respectively (one application) and 125.5 and 134.5 % (two applications), respectively during four growing seasons. Followed by soil solarization which increased by 96.4 and 109.1% during four growing seasons when applied at once and twice applications, respectively.

Using of soil sterilization with hot water treatments for controlling several soil-borne diseases were reported about Fusarium wilt of spinach ,(Kuniyasa *et al.*, 1993 and Iwamoto *et al.,* 2000) and Fusarium wilt of Chrysanthemum (Iwamoto *et al*., 2005). Reduction in the disease incidence and increasing of yield due to soil solarization were reported by many investigators (Katan, 1980 and Osman *et al.*, 1986). Pullman *et.al.*(1981) presented a detailed study on thermal death of four soil-borne plant pathogens as affected by time and temperature of the treatment. They reported that *R. solani* was killed at 50^{o}C in only 10 minutes at exposure time.

The inability of organisms to tolerate high temperatures is related to an upper limit on 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, two 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 or filth 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, 1986 and Stapleton *et al.*, 1985).

The hot water treatment observed prominent growth promoting effects on any crops by the hot water treatment probably due to the conspicuous improvement of the chemical and physical soil property as a result of the washout by the huge amount of hot water. Some pioneering growers of greenhouse tomato and rose have already been adopting this technology for more than 10 years (Noling, 1995; Uematsue *et al.*, 2003 and Kita *et al*., 2003). It is noticed that the hot water applied either Sprinklers or Buried pipes system was similar in their effect with pesticide Basamid for suppressition the cucumber root diseases but significantly differences between their effect on cucumber yield which increased fruit yield ranged between (44.4 to 51.6 %) as compared with pesticide Basamid.

It could be suggested that hot water applied as Buried hot water pipes or Sprinklers systems and soil solarization as soil treatments might be safely used commercially for controlling root diseases of cucumber plants under greenhouse conditions.

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