ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 12, June 2014

Physical and Biological Treatments as Integrated Control Measures against Tomato Root Diseases under Field Conditions

R.S.R. El-Mohamady, Nehal S. El-Mougy, M. M. Abdel-Kader, Mejda Daami-Remadi

Abstract - The efficacy of soil mulching and/ or bio compost (compost fortified with bio control agent, Trichoderm harzianum) and the bio agent T. harzianum for managing of the major fungal root pathogens of tomato plants under field conditions. Results indicated that all treatments significantly reduced diseases incidence and severity of grown tomato plants comparing with untreated control. Moreover, soil mulching in combination with bio-compost and T. harzianum treatments significantly reduce the incidence of root rot, crown and root rot and wilt disease incidence and severity after 30 and 60 dye of transplanting tomato seedlings in treated soil comparing with untreated soil (control). The population density of Fusarium spp. was decreased in mulched soils at the end of experimental period. However, soil solarization was more effective in reducing the pathogen's population either alone or combined with bio compost treatment. This effect was observed to be lesser with increasing soil depths. The same trend was also noticed in fallow unmulched soil (control) at the two similar depths. Some of plant morphogenesis, e.g. averages of plant height, number of branches/plant showed significant increase in tomato plants grown in mulched soil with biocompost and bioagent application. Furthermore, there was a significant effect of the soil mulching and bio compost treatments on the quantitative parameters, i.e. no. of fruits/ plant, fruit weight plant (kg), fruit weight (g) and total yield Fadden (t) of tomato fruit yield. On the light of obtained results in the present study, it could be suggested that combined treatment between bio compost and soil mulching might be used commercially for controlling tomato crown rot disease under field conditions in organic farming.

Index Terms—**bio compost, crown rot, Fusarium spp., root rot, solarization, tomato, T. harzianum.**

I. INTRODUCTION

Tomato plants (*Solanum lycopersicum* L.) considered one of the most important vegetable crops in Egypt and Tunisia as well as other countries in the world. Root rot disease caused *by Fusarium oxysporium*, *Rhizoctonia solani* Kuhu; *Fusarium solani* (Mart) Sacc. and *Sclerotium rolfsii* Sacc. are the most destructive disease of tomato [1,2]. Root and crown rot as well as wilt diseases of tomato caused by *Fusariun oxysporum f.sp. lyucopersci* and *F usarium oxysporun f sp radicis lycopersci* pathogens which survive in soil are responsible for serious losses in vegetables crop yield [3,4,5,6]. Controlling such diseases mainly depend on fungicides treatments [7]. In this regards, fungal plant pathogens can cause devastation in these crops under appropriate environmental conditions. The challenges for producers in managing these diseases are ever-increasing, as consumer demand for year-round production of fresh vegetables with reduced or no pesticide residues continues to grow. Additionally, resistance of pathogens to pesticides has rendered certain pesticides ineffective, creating a need for new ones with other modes of action. Concerns over the potential impact of disease management practices including the use of fungicides on the environment or on consumer health have prompted producers to examine alternative methods to combat fungal diseases. There is a growing need to develop alternative approaches for controlling plant diseases. Physical treatment (soil solarization) and/ or bio-compost are characterized as having a wide range of effects could be used as alternative fungicides treatments to control soil borne plant pathogens [8,9,10,11,12]. Soil solarization proved to be an efficiency means as effective method to control soil borne pathogens. Several investigators reported the efficacy of soil solarization in reducing the incidence and severity of plant diseases caused by soil borne pathogens [13,14,15]. Many researches had been done using the biological control as viable and reliable practice against many soil borne pathogens in modern agriculture [16,17]. Moreover, the effect of soil solarization combined with the antagonistic microbes or fungicides application to control soilborne pathogens was studied by many workers. The efficacy of biological control in solarized soil was studied by. They suggested that a suppressiveness phenomenon was developed in solarized soil in addition to introduced the antagonists *Bacillus* spp. which reflected on reduction in the incidence of bean root rot and tomato wilt caused by *Sclerotium rolfsii* and *F. oxysporum* f.sp. *lycopersici*, respectively. Furthermore, [19] applied *Trichoderma harzianum* in solarized soil to control tomato wilt caused by *F. oxysporum* f.sp. *lycopersici* and reported that disease incidence was significantly reduced by this treatment. On the other hand, the incidence of several soil-borne plant pathogens has also been reduced by using composts made of different raw materials [20,21]. *Trichoderma*, in combination with composts from agricultural wastes, was used to suppress *Rhizoctonia solani* in cucumber seedlings [22], and *Trichoderma* sp. and sewage sludge compost were used to suppress Fusarium wilt of tomato [23]. Currently, it is believed that a combination of antagonistic microbes with mature

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 12, June 2014

compost may be more efficient in inhibiting disease than using single antagonistic microbial strains or compost alone [22,23,24]. Furthermore, with the knowledge of the adverse effects of synthetic fungicides worldwide, attention is rapidly, being shifted to non-synthetic, safer alternatives. The present work focuses on finding compounds that are safe to humans and the environment. An alternative to pesticide application is that, it may be possible to utilize a scheme which may provide protection against a broad spectrum of disease-causing pathogenic microorganisms.

II. MATERIALS AND METHODS

The field experiment was designed to investigate the effectiveness of biological and physical means to control major fungal soil borne diseases of tomato. Integration between soil mulching alone or in combination with bio compost (compost fortified with the bio control agent, *Trichoderma harzianum*) in management of the major fungal root rot, crown rot and wilt pathogens of tomato plants under field production. For achieving this target the following procedures were carried out for two successive growing seasons 2012 and 2013.

(a) Mass production of Trichoderma harzianum inoculums

One isolates of *Trichoderma harzianum* obtained from the Plant Pathology Department of the National Research Centre, Giza, Egypt was used in the present study. This microorganism was isolated from the rhizosphere of various healthy and root rot infected leguminous crops, grown in the Delta and Middle Egypt regions, and proved its high antagonistic ability during previous work at the same department. *Trichoderma harzianum* isolate was grown in conical flasks containing 250 ml potato dextrose broth PDA medium at 28±1°C for 8 days. Then, the mycelial mats were harvested and the culture filtrates were collected and stored at 4°C. The culture filtrates thus obtained were stored at 4°C. The mycelial mat was multiplied by growing on a substrate consisting of 2:1 bagaase powder and wheat bran with a small quantity of malt extract in sterilized plastic bags for 14 days at 28±1°C.

(b) Bio compost (fortified compost)

Two types of compost were used in this study. The first (compost-1) was made from agricultural wastes and the second (Compost-2) made from animal manure. These types of compost were purchased from El-Nile Company, Egypt. Fortified Compost-1 and 2 were mixed thoroughly at the rate of 1.0% (v/w) with suspension of the bio agent *T. harzainum* which previously incubated in potato dextrose broth culture on a 170 rpm shaker at $28\pm^{10}$C for 5 days.

(c)Soil mulching

On the July, 15 up to the end of August, all plots were irrigated to field capacity and 12 plots were covered with 80µm thick transparent polyethylene sheets for 6 weeks, then removed. Maximum and minimum degrees of soil temperature were regularly measured, at the depths of 0-10 and 10-20cm, during the mulching period. The average temperature at the two soil depths was calculated at the end of mulching period. Soil temperature was monitored throughout the mulching period with the aid of two mercury in steel distance-type thermographs, one of which was installed in a mulched and one in a non-mulched plot, at 10 to 20 cm of soil depths. The mean daily maximum and minimum temperatures in mulched and unmulched soil were determined. The average maximum and minimum temperatures were recorded.

(d)Effect of soil mulching and /or bio compost on the population density of Fusarium **spp**.

The population densities of *Fusarium* spp. were determined by assaying soil samples in the laboratory, using serial dilutions on modified peptone –PCNB agar medium, as described [25]. From each experimental plot, 10 samples were taken at two soil depths, 0-10 and 10-20 cm then bulked into one composite sample. Soil sampling was done before and after the treatments. The efficiency of soil mulching and bio compost treatments on Fusarium density in soil was expressed as propagules counts (cfu $x10^3$ g/dry soil). Total count of *Fusarium* spp. in solarized and unsolarized soil, compared with their count before soil mulching, was estimated using the plate count technique after [26]. Soil temperature was monitored throughout the mulching period with the aid of two mercury in steel distance-type thermographs, one of which was installed in a mulched and one in a non-mulched plot, at 10 to 20 cm of soil depths. The mean daily maximum and minimum temperatures in mulched and unmulched soil were determined. The average maximum and minimum temperatures were recorded.

Experimental Field

Field experiment was established in naturally heavily infested sandy-clay soil with tomato phytopathogenic microorganisms causing tomato root rot, crown rot and wilt diseases. This field had been chosen during the author's survey in the previous season. The experimental field conducted at private farm located at El-Kanater El-Khaireia, Qalubeia governorate. The field experiment consisted of 24 plots (42 m² each and 12Lx3.5W)) each comprising of 12 rows and 30 cm spacing between plants. The applied treatments were as follows:

Single treatments*:*

1- Bio –compost 1.
2- Bio compost 2.
3- mulched soil
4- *Trichoderma harzianum*

Combined treatments:

5- Mulched soil + Bio –compost 1.
6- Mulched soil + Bio –compost 2.
7- Mulched soil + *Trichoderma harzianum.*
8 **-** Non mulched soil and non treated seedling.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 12, June 2014

After removal the polyethylene sheets the following treatments were applied. The bioagent *T. harzianum* introduced to the soil in the form of fungal inoculum grown on bagaase + wheat bran medium (2:1) as mentioned above. Meanwhile, fortified compost introduced to the soil in the form of fungal inoculum mixed with compost types. All the above mentioned treatments were applied at rate of $20m^3$/feddan ($4200m^2$). Compost, fortified compost and bioagent inoculum were incorporated into the same cultivated row site on the top of 20 cm of the soil surface considering relevant treatments [27]. The experimental field was irrigated after treatments application. Tomato seedlings c.v. Super Marmand were transplanted after 14 days of treatments application. This tomato c.v. Super Marmande is known to be susceptible to all root rot, crown rot and wilt pathogens. All treatments were applied in completely randomized block design with three replicates (plots) for each particular treatment. The percentage of disease infection and severity were recorded after 30 and 60 days of transplanting of each treatment as well as check treatment (control) for each growing season. The average percentages of disease incidence and severity were calculated.

Disease assessments

(a) Diseases incidence

Root rot, crown rot and wilt diseases incidence were assessed on the basis of field symptoms at 30-day intervals during the growing season. All infected plants were picked up and examined for the causal organism for specific root disease. Root samples were also subjected to isolation for the pathogens in the laboratory.

(b) Diseases severity

Root rot and wilt severity were estimated at 30 and 60 days after transplanting according to [29] using a rating scale of (0 – 5) on based on root discoloration or leaf yellowing grading, *viz.*, 0 = neither root discoloration nor leaf yellowing, 1= 1-25% root discoloration or one leaf yellowing 2= 26-50% root discoloration or more than one leaf yellowing, 3= 51-75% root discoloration with one wilted leaf, 4= up to 76% root discoloration or more than one leaf wilted, and 5= completely dead plants.

Statistical analyses

All experiments were set up in a complete randomized design. One-way ANOVA was used to analyze differences between antagonistic inhibitor effect and linear growth of pathogenic fungi *in vitro*. A general linear model option of the analysis system SAS [30] was used to perform the ANOVA. Duncan's multiple range test at $P < 0.05$ level was used for means separation [31].

III. RESULTS AND DISCUSSION

Measurement of soil temperatures during mulching period

Average of maximum and minimum soil temperatures in mulched and non- mulched soil was recorded during mulching period. Results in Table (1) indicate that maximum soil temperatures in mulched was increased by 15.0, and 14.3 °C at depths of 1-10 and 10-20 cm of soil surface as compared with un-mulched soil. The highest increase in soil temperatures was obtained with mulched soil which recorded 56.5 and 51.5 °C as maximum soil temperatures at two soil depths, respectively. In this concern, [32] a detailed study on thermal death of four soilborne plant pathogens as affected by time and temperature of the treatment was presented. They reported that temperatures of 37–50°C for different time periods were lethal to mycelia, spores, and resting structures of *Verticillium dahliae*, *Pythium ultimum*, and *Thielaviopsis basicola*. They added that that *Rhizoctonia solani* was found to be killed at 50°C in only 10 min. as exposure time. In the present study, the recorded soil temperature measured at 0-10 cm and 10-20 cm of soil depths in mulched soil reached average of 56.5 and 51.5°C during six weeks of mulching period.

Table (1) Average of maximum and minimum soil temperatures in mulched and un-mulched soil during July and August of two successive seasons 2012-2013

Treatment	Average of maximum and minimum soil temperatures (°C)			
	Soil depth (cm)			
	0-10		10-20	
	Min.	Max.	Min.	Max.
Mulched soil	40.2	56.5	37.0	51.5
Un- mulched soil	25.0	41.5	27.0	37.2

***Effect of soil mulching and /or bio compost on the population density of Fusarium* spp.**

The population density of *Fusarium* spp. were determined in naturally infested soil either in mulched and /or bio compost treated soil comparing with unmulched one. Data shown in Table (2) indicate that fungal populations decreased in mulched soils at the end of experimental period. However, solarization was more effective in reducing the pathogen's population either alone or combined with bio compost treatment. This effect was observed to be lesser with increasing soil depths. The same trend was also noticed in fallow unmulched soil (control) at the two similar depths. It is interesting to note that the population density of *Fusarium* spp. showed the highest sensitivity to solar treatment combined with bio compost followed bio composted soil and mulched only soil. This trend was also observed at the two depths in both solarized and unsolarized soils. These results are in agreement with those of [33,34], who demonstrated that the population of soilborne fungi, *i.e. Fusarium oxysporum*, *Rhizoctonia solani* and *Sclerotium rolfsii*, reduced by 62 to 100% at 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.

Table (2) Average Population densities of *Fusarium* spp. in response to soil mulching and/or bio compost treatments under field conditions for the two successive seasons 2012-2013

Treatment	Soil	Population densities of Fusarium spp.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 12, June 2014

	Depth (cm)	(cfu 5x10 ^{3} g/dry soil)		
		*Before treatment	**After treatment	Reduction %
Bio compost 1	10 cm	3.6 a	1.9 bc	47.2
	20 cm	4.0 a	2.4 b	40.0
Bio compost 2	10 cm	3.6 a	1.7 bc	52.7
	20 cm	4.1 a	2.3 b	43.9
mulched soil	10 cm	3.2 a	1.6 bc	50.0
	20 cm	3.6 a	2.2 b	38.8
T. harzianum	10 cm	3.4 a	2.0 b	41.1
	20 cm	3.8 a	2.6 b	31.5
Bio compost 1 + mulched soil	10 cm	3.8 a	0.9 bc	76.3
	20 cm	4.1 a	1.3 bc	68.2
Bio compost 2 + mulched soil	10 cm	3.5 a	0.9 bc	74.2
	20 cm	3.9 a	1.1 bc	71.7
T. harzianum + mulched soil	10 cm	3.0 a	1.1 bc	63.3
	20 cm	3.1 a	1.5 bc	51.6
Control (un mulched soil)	10 cm	4.0 a	2.6 b	35.0
	20 cm	3.3 a	2.8 b	15.0

Figures with the same letter are not significantly different ($P \leq 0.05$).

Effect of soil mulching and /or bio compost on diseases incidence and severity

Tomato root diseases incidence and severity were evaluated in naturally infested soil with disease pathogens exposed to mulching and /or bio compost treatments. Data in Table (3) showed that significant reduction in diseases incidence was observed in mulched soil alone or when combined with bio compost or *T. harzianum,* than similar treatments in unmulched soil. Soil mulching alone or in combination with bio compost as soil treatment were applied to control root diseases of tomato plants grown under field conditions during 2012 and 2013 seasons. Results in Table (3) show that all soil mulching and bio-compost treatments significantly reduce the incidence of root rot, crown and root rot and wilt disease after 30 and 60 dye of transplanting tomato seedlings in treated soil comparing with untreated soil (control). The highest reduction in disease incidence was recorded in mulched soil combined with bio compost-2 treatment reduced Fusarium root rot, crown rot and wilt by 66.2, 60.0 52.8% and 72.2, 71.8, 58.2% after 30 and 60 day of transplanting, respectively. Similarly, reduction by 61.0, 46.2, 48.2% and 70.6, 72.4, 54.0% as well as 56.2, 51.4, 45.0% and 64.2, 62.0, 52.6% in Fusarium root rot, crown rot and wilt diseases incidence was recorded at compost-1 and bioagent combined with mulching treatments in respective order after 30 and 60 dye of transplanting. Furthermore, the recorded diseases severity of tomato plants followed similar trend. Higher reduction of disease severity of root rot, crown rot and wilt were recorded in tomato plants grown in mulched soils combined with bio compost-2 followed by bio compost-1 and bioagent comparing with the same treatments applied in unmulched soil as well as untreated control (Table, 4). The highest reduction in disease severity was recorded in mulched soil combined with bio compost-2 treatment reduced Fusarium root rot, crown rot and wilt by 53.2, 64.2, 53.8% and 60.8, 68.0, 58.2% after 30 and 60 day of transplanting, respectively. Also, similar trend was also observed in bio compost and bioagent combined with mulching treatment.

Table (3) Effect of soil mulching and/ bio compost treatments on the incidence of root diseases of tomato plants grown under field conditions 2012/2013

Treatment	Root disease incidence (%) *					
	Root rot	R (%)	Crown rot	R (%)	Wilt	R (%)
After 30 days of transplanting						
Bio compost 1	14.8 c	44.8	13.6 c	33.0	10.9 b	28.2
Bio compost 2	13.2 c	50.6	11.8 d	41.4	10.4 b	31.6
T. harzianum	18.8 b	30.2	15.8 b	22.8	12.2 b	19.2
mulched soil	12.1 d	55.2	13.3 c	34.6	9.4 b	37.8
Bio compost 1 + mulched soil	10.5 e	61.0	11.0 d	46.2	7.9 c	48.2
Bio compost 2 + mulched soil	9.1 e	66.2	8.2 e	60.0	7.2 d	52.8
T. harzianum + mulched soil	11.8 d	56.2	9.9 e	51.4	8.4 d	45.0
Control (untreated)	27.0 a	0.0	20.4 a	0.0	15.2 a	0.0
After 60 days of transplanting						
Bio compost 1	16.0 c	51.8	14.9 c	44.2	13.1 b	38.8
Bio compost 2	12.9 d	61.0	12.1 d	55.0	11.8 c	45.0
T. harzianum	21.9 b	34.0	18.3 b	31.8	13.5 b	26.8
mulched soil	13.2 d	60.2	11.5 d	57.0	10.9 c	48.8
Bio compost 1 + mulched soil	9.8 e	70.6	7.4 e	72.4	9.8 d	54.0
Bio compost 2 + mulched soil	9.2 e	72.2	7.5 e	71.8	8.9 d	58.2
T. harzianum + mulched soil	11.9 d	64.2	10.2 d	62.0	10.1 c	52.6
Control (untreated)	33.2 a	0.0	26.8 a	0.0	21.4 a	0.0

* Average percentages of diseases incidence for the two successive seasons 2012-2013

Figures with the same letter are not significantly different ($P \leq 0.05$).

In this regards, Fusarium diseases inhabit most tomato-growing regions worldwide, causing tomato production yield losses. Fungal phytopathogens are cause of many plant diseases and much loss of crop yields, especially in tropical and subtropical regions [35,36]**.** *Fusarium oxysporum* is major soilborne fungal pathogens of both greenhouse and field grown tomatoes in the warm vegetable growing areas of the world [37]. Fusarium wilt of tomato caused by *Fusarium oxysporum* f. sp. *lycopersici* and *Rhizoctonia solani* causing damping off, cankers, root rots, fruit decay, foliage disease causes serious economic loss. *Fusarium oxysporum* penetrates the roots mainly through wounds and proceeds into and throughout the vascular system, leading to functional collapse, systemic wilting and often the death of the infected plant *Fusarium oxysporum* f. sp. *radicis-lycopersici* cause disease on hosts from several plant families, including tomato in the greenhouse [38]. Fusarium crown and root rot of tomato often referred to as ‘crown rot’ [39]. Crown rot develops primarily in cool climates in both field and greenhouse tomatoes. Substantial crop losses in infected fields have given the disease international attention. *Fusarium oxysporum* f. sp. *lycopersici* causes disease only in plants of the genus *lycopersicon* [40] and inhabits most tomato growing

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 12, June 2014

regions worldwide, causing tomato production yield losses [41]. This fungus responsible for vascular wilt disease in tomato and infects the vascular system of roots, inhibiting water transport, which in turn results in rapid plant death [42,43].

Table (4) Effect of soil mulching and/ bio compost treatments on the severity of root diseases of tomato plants grown under field conditions 2012/2013

Treatment	Root diseases severity (%) *					
	Root rot	R (%)	Crown rot	R (%)	Wilt	R (%)
After 30 days of transplanting						
Bio compost 1	1.1 c	33.4	1.4 b	31.8	0.9 c	30.8
Bio compost 2	1.0 c	43.2	1.2 b	42.2	0.9 c	33.0
T. harzianum	1.4 b	24.6	1.5 b	23.0	1.1 b	18.8
mulched soil	0.9 d	47.8	1.2 b	42.4	0.9 c	35.6
Bio compost 1 + mulched soil	0.8 d	55.0	0.8 c	62.0	0.7 c	50.0
Bio compost 2 + mulched soil	0.8 d	53.4	0.7 c	64.2	0.6 d	53.8
T. harzianum + mulched soil	1.0 c	44.8	1.0 bc	48.4	0.8 cd	41.0
Control (untreated)	1.8 a	0.0	2.0 a	0.0	1.4 a	0.0
After 60 days of transplanting						
Bio compost 1	1.2 b	40.0	1.8 c	36.2	1.2 c	32.4
Bio compost 2	0.9 c	50.4	1.5 d	46.0	1.1 c	38.4
T. harzianum	1.4 b	30.2	2.0 b	26.2	1.4 b	22.0
mulched soil	0.9 c	51.6	1.4 d	50.0	1.0 c	41.2
Bio compost 1 + mulched soil	0.8 c	61.0	1.1 e	61.2	0.8 d	54.2
Bio compost 2 + mulched soil	0.8 c	60.8	1.0 e	68.0	0.8 d	58.2
T. harzianum + mulched soil	0.9 c	52.8	1.3 e	53.2	0.9 d	46.0
Control (untreated)	2.0 a	0.0	2.8 a	0.0	1.8 a	0.0

* Average percentages of diseases incidence for the two successive seasons 2012-2013
Figures with the same letter are not significantly different ($P \leq 0.05$).

Therefore, several investigators conducted with applying physical and biological control measures as fungicides alternatives against soilborne plant pathogens. Vegetable producers confronted with the challenges of managing fungal pathogens have the opportunity to use physical and biological control agents. Several commercially available products have shown significant disease reduction through various mechanisms to reduce pathogen development and disease. Plant diseases need to be controlled to maintain the quality and abundance of food, feed, and fiber produced by growers around the world. Different approaches may be used to prevent, mitigate or control plant diseases. Beyond good agronomic and horticultural practices, growers often rely heavily on chemical fertilizers and pesticides. Such inputs to agriculture have contributed significantly to the spectacular improvements in crop productivity and quality over the past 100 years. However, the environmental pollution caused by excessive use and misuse of agrochemicals, as well as fear mongering by some opponents of pesticides, has led to considerable changes in people's attitudes towards the use of pesticides in agriculture. Today, there are strict regulations on chemical pesticide use, and there is political pressure to remove the most hazardous chemicals from the market. Additionally, the spread of plant diseases in natural ecosystems may preclude successful application of chemicals, because of the scale to which such applications might have to be applied. Consequently, some pest management researchers have focused their efforts on developing alternative inputs to synthetic chemicals for controlling pests and diseases. Among these alternatives are those referred to as biological control. The application of biological controls using antagonistic microorganisms has proved to be successful for controlling various plant diseases in many countries [44]. However, this is not an easy method, and it is costly to apply; however it can serve as the best control measure under greenhouse conditions. *Trichoderma harzianum* introduced to the soil, was able to reduce root rot incidence of faba bean plants significantly more than the fungicide Rizolex-T [27]. In recent years, several attempts have been made to overcome this obstacle by applying antagonistic microorganisms. *Trichoderma* spp. are well documented as effective biological control agents of plant diseases caused by soil-borne fungi [45,46,47]. Many investigators [48,49] observed that the application of wheat bran colonized by *T. harzianum* to soil infested with *R. solani* and *S. rolfsii*, reduced the incidence of root diseases caused by these pathogens.

Effect of soil mulching and /or bio compost on tomato plant growth and produced yield

Some of plant morphogenesis, *e.g.* averages of plant height, number of branches/plant were measured as well as the number of fruits/plant, fruit weight/plant (kg), fruit yield/Fadden (ton) and the increase of yield were calculated at the end of the growing season. Presented data in Table (5) show that the most effective treatments on plant height and number of branches/plant were recorded as76.4 cm, 4.6 branches at the treatment of bio-compost 2 in mulched soil, followed by 73.6 cm, 4.2 branches at treatment of bio-compost-1 in mulched soil and 70.0 cm, 4.2 branches at treatment of *T. harzianum* in mulched soil, respectively. Similar trend in a lesser records was observed for the same treatments applied in un mulched soil. Furthermore, reduction in disease incidence means increasing in plant stand and growth parameters, which reflect on the obtained tomato fruit yield. There was a significant effect of the soil mulching and bio compost treatments on the quantitative parameters, *i.e.* no. of fruits/ plant, fruit weight plant (kg), fruit weight (g) and total yield Fadden (t) of tomato fruit yield. Results in Table (5) show that all compost and mulching treatments were significantly improve the quantity and quality parameters of tomato yield if compared with untreated plants (control).The most effective treatments were observed in mulched soil followed by application with bio-compost-2, bio-compost-1 and *T. harzianum*, respectively for all fruit quantity. They had high records as 54, 51, 50 (No. of fruit /plant); 2.8, 2.5, 2.2 (Fruit weight plant/Kg); 124, 121, 119 (fruit weight/g) and increasing total yield Fadden which recorded as 65.2, 63.5 and 59.3 %, respectively. Also, similar trend was observed in a lesser extent concerning the same treatments when applied in un mulched soil.

Table (5) Average measurements of some growth parameters and yield of tomato plants in response to soil mulching and/or bio compost treatments under field conditions for the two successive seasons 2012-2013

Treatment	Plant morphogenesis		Yield				
			Fruit quality			Fruit yield	
	Plant height (cm)	No. of branch /plant	No. of fruit /plant	Fruit Wt pl/Kg	Fruit Wt. (g)	Ton/ Fedden	Increase %
Bio compost 1	65.2 a	3.8 a	44 c	2.0 bc	107 b	17.2 c	48.7
Bio compost 2	68.8 a	3.5 a	47 c	2.1 bc	114 b	17.4 c	47.4
T. harzianum	67.4 a	3.2 a	39 b	1.8 b	99 b	15.6 b	32.2
mulched soil	62.0 a	3.0 a	48 cd	2.2 c	116 b	17.6 c	49.1
Bio compost 1 + mulched soil	73.6 b	4.2 b	51 cd	2.5 c	121 c	19.3 d	63.5
Bio compost 2 + mulched soil	76.4 b	4.6 b	54 cd	2.6 c	124 c	19.3 d	65.2
T. harzianum + mulched soil	70.0 b	4.2 b	50 cd	2.2 c	119 c	18.8 d	59.3
Control (untreated)	56.4 c	2.8 c	31 a	1.4 a	74 a	11.8 a	0.0

Figures with the same letter are not significantly different ($P \leq 0.05$).

In this concern, it was reported that reduction of disease incidence with fungicides treatments was followed by an increase in fresh and dry weight, shoot and root length, number of branches, number of leaves, number of nodules, and the yield [50,51]. Moreover, soil amendment with agricultural wastes alone or in combination with bio-control agents was recommended for controlling soil borne pathogens and increasing the yield of many crops. Sugarcane residues (bagasse) degraded by *Trichoderma* spp. was used as soil amendment to improve growth and yield of rice and pea [52]. However soil mulching was found in the present study to reduce the Fusarium infection of tomato but the magnitude was not much expressed as that by the actual resulted yield. In this regard, [33] were first to review the idea of control of soilborne diseases through mulching the soil. They also presented evidence of drastic effect on population of *Fusarium oxysporum* f. sp. *lycopersici* as well as several other soilborne plant pathogenic fungi which was reflected by more healthy eggplant and tomato plants. Furthermore, many report emphasized the good effect of soil solarization as a control measure for soilborne plant pathogens beside beneficial side effect on plant growth. Among the crops studied, solarization treatment increased yield of peanut by 50% [53], of potatoes by 35% [54], of cotton by 40-70% [55] and of onion by 125% [56]. The phenomenon of increased plant growth which was observed in solarized soil was explained by [34]. He proposed several mechanisms which may be responsible for such out growth, including release of minerals in the soil, stimulation of beneficial microorganisms and control of minor pathogens. He found, in his study, increased amounts of soluble minirals, e.g. NO_3, NH_4^+, K^+, Ca^{++} and organic materials in solarized soil.

The obtained results in the present study lead to conclude that soil solarization and biological control are considered as non-chemical control methods which have advantage and limitation. Therefore, application of bio compost or biological agents, as soil introduction in solarized soil, could be used as an effective and safe applicable technique for controlling soilborne diseases in addition to avoid environmental pollution due to decrease the usage of chemical fungicides. The integration of solarization with biological and cultural methods may improve the control of soilborne pathogens, especially these caused root rot diseases.

ACHNOLEDGEMENT

This work was carried out during a Collaborative project Tunisia-Egypt Funded by Ministry of Scientific Research, in Egypt (Grand no.4/10/4) and the Ministry of, Higher Education and Scientific Research of Tunisia.

REFERENCES

[1] Benhamou, N.; Lafontaine, P.J. and Nicole, M. 1994. Seed treatment with chitosan induces systemic resistance to Fusarium crown and root rot in tomato plants. Phytopathology 84:1432-1444.

[2] El-Mougy, N.S. 1995. Studies on wilt and root rot diseases of tomato in Egypt and their control by modern methods. M.Sc. Thesis, Faculty of Agriculture, Cairo University, Egypt, pp. 178.

[3] Lobo, J.L. and Silva, L. 2000. "Sclerotinia rot losses in processing tomatoes grown under centre pivot irrigation in central Brazil. Plant Pathology", 49, 51–56.

[4] Radwan, M.B. and AL-Masri, M.I. 2012, Enhanced Soil Solarization against Fusarium oxysporum f. sp. lycopersici in the Uplands. International Journal of Agronomy, 7: 1-7.

[5] El-Mohamedy, R.S.R., Abdel-Kader, M.M., Abd-El-Kareem, F. and El-Mougy, N.S. 2013a, Inhibitory effect of antagonistic bio-agents and chitosan on the growth of tomato root rot pathogens In vitro. Journal of Agricultural Technology, 9 (6):1521-1533.

[6] Amira, M. Abu Taleb; Nagwa, A. Tharwat; El-Mohamedy, R.S.R. 2013. Induction of Resistance in Tomato Plants against Fusarium Crown and Root Rot Disease by Trichoderma harzianum and Chitosan. Egyptian Journal of Phytopathology, 41(1) :13-26.

[7] Rauf, B.A. 2000. Seed-borne disease problems of legume crops in Pakistan. Pak. J. Sci. and Industrial Res., 43:249-254.

[8] El-Shanawany, A.A., El-Ghamery, A.A., El-Sheikh, H.H. and Bashandy, A.A. 2004, Soil solarization and the

composition of soil fungal community in upper Egypt. Ass. Univ. Bull. Environ. Res., 7 (1): March 2004.

[9] Afrozi, A. Ashrafuzzaman, M., Ahmedm, M.N. and Ali, M.E. 2008, Integrated management of major fungal diseases of tomato .Int. J. Sustain. Crop Prod., 3(2):54-59.

[10] Farrag, E.S.H., Fotouh, Y.O. 2010, Solarization as a method for producing fungal-free container soil and controlling wilt and root-rot diseases on cucumber plants under greenhouse conditions. Archives of Phytopathology and Plant Protection 43, 519 – 526.

[11] El-Mougy, N.S., Abdel-Kareem, F., Abdel-Kader, M.M., Fatouh, Y.O. 2013, Long term effect of applied compost and bio-agents as integrated treatment for controlling bean root rot disease in solarized soil under field conditions. Plant Pathology & Quarantine, 3(1), 41–52.

[12] El-Mohamedy, R.S.R., Morsy, A.A and Abd Radi, T.B. 2013b, Utilization of bio composted agricultural wastes in management of Fusarium dry root rot disease on lime (Citrus aurantifolia L.). Journal of Agricultural Technology, 9(5):1227-1239.

[13] Martyn, R.D. and Hartz, T.K. 1986. Soil solarization for control of Fusarium wilt of watermelon. Phytopathology, 76: 402. (Abstr.).

[14] Greenberger, A.; Vogev, A. and Katan, J. 1987. Induced suppressiveness in solarized soils. Phytopathology, 77: 1663-1667.

[15] Abdel-Kader, M.M. and Ashour, A.M.A.1999. Biological control of cowpea root rot in solarized soil. Egypt. J. Phytopathol., 27: 9-18.

[16] Adams, P.B. 1990. The potential of mycoparasites for biological control of plant disease. Ann. Rev. Phytopathol., 28: 59-72.

[17] Campbell, R.1990. Biological control of soilborne diseases, some present problems and different approaches. Crop. Protection, 13: 4-13.

[18] Greenberger, A.; Vogev, A. and Katan, J. 1984. Biological control in solarized soils. Proc. of 6th Con. Phytopathol. Mediterr. Un. Egypt, pp. 112-114.

[19] Yucel, S. and Cali, S. 1997. Studies on the effect of soil solarization combined with fumigant and antagonists in greenhouse to control soilborne pathogens in the East Mediterranean region of Turkey. 2nd International Conf. on Soil Solarization and Integrated Management of Soilborne Pests. ICARDA, Aleppo, Syria, Abstracts.

[20] Lumsden, R.D.; Lewis, J.A. and Millner, P.D. 1983. "Effect of composted sewage sludge on several soilborne pathogens and diseases," Phytopathology, vol. 73 (11):1543–1548.

[21] Borrero, C.; Trillas, M.I.; Ordov´as, J.C.; Tello, J.C. and Avil´es, M. 2004. "Predictive factors for the suppression of Fusarium wilt of tomato in plant growth media," Phytopathology, 94 (10): 1094–1101.

[22] Trillas, M.I.; Casanova, E.; Cotxarrera, L.; Ordov´as, J.; Borrero, C. and Avil´es, M. 2006. "Composts from agricultural waste and the Trichoderma asperellum strain T-34 suppress Rhizoctonia solani in cucumber seedlings," Biological Control, 39 (1): 32–38.

[23] Cotxarrera, L.; Trillas-Gay, M.I.; Steinberg, C. and Alabouvette, C. 2002. "Use of sewage sludge compost and Trichoderma asperellum isolates to suppress Fusarium wilt of tomato," Soil Biology and Biochemistry, 34 (4): 467–476.

[24] Sivan, A. and Chet, I. 1992. "Microbial control of plant disease," In Environmental Microbiology, R. Mitchell, Ed., pp. 335–354, Wiley, New York, NY, USA.

[25] Ioannou, N., and Poullis, C.A. 1990. Evaluation of soil solarization for control of Fusarium wilt of watermelon. Technical Bulletin 121, Agricultural Research Institute, Nicosia.

[26] Louw, H.A. and Webely, D.W. 1959. The bacteriology of root region of the oat plant grown under controlled pot culture conditions. J. Appl. Bacteriol., 22: 216-226.

[27] Abdel-Kader, M.M. 1997. "Field application of Trichoderma harzianum as biocide for control of bean root rot disease". Egypt. J. Phytopathol., 25: 19-25.

[28] Abdou, E., Abd-Alla, H.M. Galal, A.A. 2001. Survey of sesame root rot/wilt disease in Minia and their possible control by ascorbic and salicylic acids. Assiut J. Agric. Sci., 1: 135-152.

[29] Abdou, E., Abd-Alla, H.M. and Galal, A.A. 2001. Survey of sesame root rot/wilt disease in Minia and their possible control by ascorbic and salicylic acids. Assiut J. Agric. Sci., 1: 135-152.

[30] SAS 1996. Statistical Analysis System. User's Guide: Statistics (PC-Dos 6.04). SAS Institute Inc., Cary, NC, USA.

[31] Winer, B.J. 1971. Statistical Principles in Experimental Design. 2nd ed. MiGraw-Hil Kogakusha, LTD, pp. 596.

[32] Pullman, G.S.; DeVay, J.E. and Garber, R.H. 1981. Soil solarization and thermal death: A logarithmic relationship between time and temperature for four soil borne plant pathogens. Phytopathology, 71: 959-964.

[33] Katan, J.; Greenberger, A.; Alon, H. and Grinstein, A. 1976. Solar heating by polyethylene mulching for the control of diseases caused by soilborne pathogens. Phytopathology, 66: 683-688.

[34] Katan, J. 1980. Solar pasteurization of soils for disease control: status and prospects. Pl. Dis. Reptr., 64: 450-454.

[35] Abd-Allah, E.F.; Hashem, A. and Al-Huqail, A. 2011. Biologically-based strategies to reduce postharvest losses of tomato. Afr. J. Biotechnol., 32: 6040-6044.

[36] Abdel-Monaim, M.F. 2012. Induced systemic resistance in tomato plants against Fusarium wilt diseases. Int. Res. J. Microbiol., 3: 14-23.

[37] Rosewich, U.L.; Pettway, R.E.; Katan, T. and Kistler, H.C. 1999. Population genetic analysis corroborates dispersal of Fusarium oxysporum f. sp. radicis-lycopersici from Florida to Europe. Phytopathology, 89: 623-630.

[38] Menzies, J.G.; Koch, C. and Seywerd, F. 1990. Addition to the host range of Fusarium oxysporum f. sp. radicis-lycopersici. Plant Dis., 74: 569-572.

[39] Fazio, G.; Stevens, M.R. and Scott, J.W. 1999. Identification of RAPD markers linked to fusarium crown

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 12, June 2014
and root rot resistance (Frl) in tomato. Euphytica, 150: 205-210.

[40] Rowe, R.C. 1980. Comparative pathogenicity and host ranges of Fusarium oxysporum isolates causing crown and root rot of greenhouse and field-grown tomatoes in North America and Japan. Phytopathology, 70:1143-1148.

[41] Staniazsek, M.; Kozik, E.U. and Marczewski, W. 2007. A CAPS marker TAO1902 diagnostic for the I-2 gene conferring resistance to Fusarium oxysporum f. sp. lycopersici race 2 in tomato. Plant Breeding. 126(3): 331-333.

[42] McGrath D.J., Gillespie G., Vawdrey L. 1987. Inheritance of resistance to Fusarium oxysporum f. sp. Lycopersici races 2 and 3 of Lycopersicom pennellii. Aust. J. Agric. Res. 38: 729–733.

[43] Malhotra, S.K. and Vashistha, R.N. 1993. Genetics of resistance to Fusarium wilt race 1 in current tomato (Lycopersicon pimpinellifolium). Indian J. Agric. Sci., 63: 246-347.

[44] Sivan A, 1987. "Biological control of Fusarium crown rot of tomato by Trichoderma harzianum under field conditions". Plant Dis., 71, 587–592.

[45] Sivan, A. and Chet, I. 1986. "Biological control of Fusarium spp. in cotton, wheat and muskmelon by Trichoderma harzianum". Journal of Phytopathology, 116: 39-47.

[46] Whipps, J.M. and Lumsden, R.D. 2001. "Commercial use of fungi as plant disease biological control agents: status and prospects". p. 9–22. In: “Fungi as Biocontrol Agents: Progress, Problems and Potential” (T.M. Butt, C. Jackson, N. Magan, eds.), CABI Publishing: Wallingford, UK.

[47] McLean, K.L.; Dodd, S.L.; Sleight, B.E.; Hill, R.A. and Stewart, A. 2004 "Comparison of the behavior of a transformed hygromycin resistant strain of Trichoderma atoviride with the wild-type strain". New Zealand Plant Protection, 57: 72-76.

[48] Hadar, Y.; Chet, I. and Henis, Y. 1979. "Biological control of R. solani damping-off with wheat bran culture of Trichoderma harzianum". Phytopathology, 69, 64–68.

[49] Elad, T.; Chet, J. and Katan, J. 1980. "Trichoderma harzianum: a biocontrol effective against Sclerotium rolfsii and Rhizoctonia solani". Phytopathology, 70, 119–121.

[50] Nofal, M.A.; Seif-El-Nasr, H.I.; Diab, M.M.; El-Nagar, M.A.A. and El-Said, S.I.A. 1990. “Effect of the systemic fungicides benlate and vitavax-captan on Aspergillus crown rot incidence of peanut plants. Annals of Agricultural Science, 35:407–415.

[51] El-Nagar, M.A.A.; El-Said, S.I.A.; Diab, M.M. and Maklad, F.M. 1990. Effect of using some fungicides and seed inoculation with Rhizobium lupini on controlling crown rot disease incidence and plant growth of peanut crop. African Journal of Agricultural Sciences, 17: 199–207.

[52] Mitra, S. and Nandi, B. 1994. Biodegraded agro industrial wastes as soil amendments for plant growth. Journal of Mycopathology Research, 32: 101–109.

[53] Grinstein, A.; Katan, J.; Abdul-Razik, A.; Zeydan O. and Elad, Y. 1979a. Control of Sclerotium rolfsii and weeds in peanuts by solar heating of the soil. Plant Dis. Reptr., 63: 1056-1059.

[54] Grinstein, A.; Orions, D.; Greenberger, A. and Katan, J. 1979b. Solar heating of the soil for the control of Verticillium dahilae and Pratylenchus thornei in potatoes. In: Schippers, B and Gams, W. (eds.) "Soilborne plant pathogens" p. 431-438. Academic Press, New York pp. 686.

[55] Katan, J.; Fisher, G. and Grinstein, A. 1980a. Solar heating of the soil and other methods for the control of Fusarium, additional soilborne pathogens and weed in cotton. Proc. Fifth Congress of Miditerranean Phytopathol. Union, pp. 80-81.

[56] Katan, J.; Rotem, I.; Finkel, Y. and Daniel, J. 1980b. Solar heating of the soil for the control of pink root and other soilborne diseases in onion. Phytopathology, 8: 39-50.

AUTHOR BIOGRAPHY

First Author: Department of Plant Pathology, National Research Centre – Egypt, Email: riadelmohamedy@yahoo.com,

Second Author: Department of Plant Pathology, National Research Centre – Egypt, Email: Nehal_nrc@yahoo.com,

Third Author: Department of Plant Pathology, National Research Centre – Egypt, Email: mokh_nrc@yahoo.com.

Fourth Author: UR13AGR09- Integrated Horticultural Production in the Tunisian Centre East, Regional Center of Research on Horticulture and Organic Agriculture of Chott-Mariem, Sousse University, 4042, Chott-Mariem, Tunisia, Email: daami_rm@yahoo.fr