
Long term effect of applied compost and bio-agents as integrated treatment for controlling bean root rot disease in solarized soil under field conditions

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Management of Bean (*Phaseolus vulgaris* L.) root rot disease caused by *Fusarium solani* and *Rhizoctonia solani* was investigated. Efficacy of *T. harzianum* and *P. fluorescens* alone or in combination with compost for controlling bean root rot disease in solarized or un-solarized soil under field conditions were studied. *In vitro* the highest reduction was obtained with *P. fluorescens* and *T. harzianum* which reduced the growth area more than 90.6 and 87.4 % for *F. solani* and *R. solani* respectively. Under field conditions, the average maximum of soil temperatures in solarized soil was increased by 15.0, 14.3 and 13.1°C at depths of 10, 20 and 30cm of soil surface as compared with un-solarized soil. The pronounced applied treatments throughout two successive growing seasons were compost A (animal waste) combined with *T. harzianum* or *P. fluorescens*, followed by compost P (agriculture waste) combined with the same bioagents in solarized soil which they reduced the root rot disease at pre-, and post-emergence growth stages, respectively. As for bean yield the highest increase was obtained at combined treatments of compost A and *T. harzianum* or *P. fluorescens*, followed by combined treatments between compost P and *T. harzianum* or *P. fluorescens* in solarized soil. Referring to the obtained results in the present study, it could be suggested that combined treatment between compost and bioagents as safety method might be used commercially for controlling bean root rot disease under field conditions.

Key words – Bean – Bio-agents – Compost – Disease control – Root rot

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Introduction

Bean plants (*Phaseolus vulgaris* L.) is one of the most important leguminous crops in Egypt. Root rot disease caused by *Fusarium solani* and *Rhizoctonia solani* is a serious and persistent disease problem of bean plants

during growing season (Filion et al. 2003; Harveson et al. 2005; Wen et al. 2005). Fungal disease control is achieved through the use of fungicides which is hazardous and toxic to both people and domestic animals and leads to environmental pollution. Therefore, a more

balanced, cost effective and eco-friendly approach must be implemented and adopted farmers. In order to overcome such hazardous control strategies, scientists, researchers from all over the world paid more attention towards the development of alternative methods which are, by definition, safe in the environment, non-toxic to humans and animals and are rapidly biodegradable. There is a growing need to develop alternative approaches for controlling plant diseases. Such strategy is use of bio-control agents to control fungal plant diseases as well as other fungicides alternatives (Sivan 1987; Punja & Utkhede 2004). *Trichoderma* spp. are effective bio-control agents for a number of soil-borne plant pathogens, and also known for their ability to enhance plant growth (Sharon et al. 2001; Rose et al. 2003). Recently, it was suggested that *Trichoderma* affects induced systemic resistance (ISR) mechanism in plants (Shoresh et al. 2005; Horst et al. 2005; Hoitink et al. 2006).

On the other hand, the incidence of several soil-borne plant pathogens have also been reduced by using composts made of different raw materials (Hoitink & Fahy 1986; Hoitink & Boehm 1999; Cotxarrera et al. 2002; Borrero et al. 2004). Since Hoitink et al. (1975) first suggested compost could be used as a peat substitute to control root pathogens, bio-control research has increasingly focused on developing the right combination of composts and antagonistic microbes. *Trichoderma* in combination with composts from agricultural wastes, was used to suppress *Rhizoctonia solani* in cucumber seedlings (Trillas et al. 2006), and *Trichoderma* sp. and sewage sludge compost were used to suppress *Fusarium* wilt of tomato (Cotxarrera et al. 2002). Currently it is believed that a combination of antagonistic microbes with mature compost may be more efficient in inhibiting disease than using single antagonistic microbial strains or compost alone (Sivan & Chet 1992; Cotxarrera et al. 2002; Trillas et al. 2006). Soil mulching was carried out as physical disease control methods using transparent polyethylene plastic placed on moist soil during the hot summer months increases soil temperatures to levels lethal to

many of soil-borne plant pathogens, weeds and nematodes (Primo & Cartia 2001; Abd-El-Kareem et al. 2004; Culman et al. 2006; Farag & Fotouh 2010). The objective of the present work was designed to evaluate the effect of *T. harzianum* and *P. fluorescens* alone or in combination with compost against bean root rot disease in solarized or un-solarized soil under field conditions.

Materials and Methods

Source of pathogenic fungi, bio-agents, bean seeds and compost

Pathogenic fungal isolates of *Rhizoctonia solani* (AG 4) and *Fusarium solani* as the causal agents of bean root rot disease were isolated from diseases bean plants grown previously from the field study located at the Experimental Research Station of National Research Centre at El-Noubaria region, Behera Governorate, Egypt.

The bio-agents, *Trichoderma harzianum* and *Pseudomonas fluorescens* were kindly obtained from culture collection unit of Plant Pathology Dept., National Research Centre, Giza, Egypt. These isolates proved their high antagonistic effect against several soil-borne plant pathogens causing root rot and wilt diseases to various vegetables and field crops in previous works at the same Department.

Bean seeds cv. Giza 3 were obtained from Vegetable Crops Research Dept., Agricultural Research Centre, Giza, Egypt. Commercial Compost A (made from animal waste) and compost P (made from agriculture waste) were purchased from Egyptian Company for Solid Waste Utilization (ECARU), Giza, Egypt, were used in field trails. Characteristics of the tested composts are shown in Table (1) as analyzed according to Page et al (1982) as follows: Compost samples were air-dried and sieved through a 2-mm mesh prior to analysis. The compost pH was potentiometrically determined in a 1:1 compost:water ratio (Mclean 1982). The compost organic carbon was determined using the Walkley-Black method (Nelson and Sommers 1982), and the total nitrogen of the

Table 1 Characterization of used composts

Compost characteristics	Value	
	Compost P (made from agriculture waste)	Compost A (made from animal waste)
PH	6.19	6.59
Electrical conductivity (E.C %)	3.01	3.12
C/N ratio	11.42	13.27
Organic matter (O.M) %	34.55	48.64
Nitrogen (N %)	3.26	6.82
Phosphorus (P %)	0.78	1.34
Potassium (K %)	2.18	3.46

compost was determined using the macro-Kjeldahl method (Bremner and Mulvaney 1982). The available phosphorus in the compost was determined using the Bray P1 method (Olsen and Sommers 1982), and the K⁺ were determined using 1 M NH₄OAc (ammonium acetate) buffered at pH 7.0 as the extractant (Thomas 1982). The exchangeable conductivity (EC) in the compost was extracted with 1 M KCl (Thomas 1982), and the extract was titrated with 0.05 M NaOH using phenolphthalein as the indicator (Odu et al. 1986).

Laboratory tests

Evaluation of the antagonistic effect of bio-agents on the growth of bean root-rot fungi was carried out *in vitro*. Two bio-agents, *T. harzianum* and *P. fluorescens* were tested for their antagonistic effect against the growth of pathogenic fungi, *R. solani* and *F. solani* under *in vitro* conditions following the methods described by Ferreira et al. (1991). The antagonistic isolates of *T. harzianum* and *P. fluorescens*, were obtained from the Plant Pathology Department of the National Research Centre, Giza, Egypt. These microorganisms were isolated from the rhizosphere of various healthy and root rot infected leguminous crops, grown in the Delta and Middle Egypt regions, and proved their high antagonistic ability during previous work at the same department. Cultures of pathogenic and antagonistic fungi grown on PDA medium

for 10 days as well as bacterial cultures which grown on nutrient broth for 2 days were used in this test. Mycelial disks (6 mm diameter) of pathogenic fungi, *F. solani* and *R. solani* were transferred singly to the center of Petri plates (9 cm diameter) containing PDA medium. Four loop growth of each antagonistic bacterium from 2-days old grown on nutrient broth cultures were placed at four corners of the plate in perpendicular positions. Disks of either *T. harzianum* or each pathogenic fungi growth were placed on opposite sides of Petri plates containing PDA medium. Inoculated plates were incubated for 7 days at 23°C. Five plates for each particular treatment were used as replicates. Growth area reduction was calculated for the pathogenic fungi using the following equation:

$$\text{Growth reduction \%} = \frac{\text{Growth area in control} - \text{growth area in treatment}}{\text{Growth area in control}} \times 100$$

Whereas: Growth area = ($\pi \times r^2$)

Field experiments

The field experiment carried out at the Experimental Research Station of National Research Centre at El-Noubaria region, Behera Governorate, Egypt. Under field conditions, the efficacy of bio-agents, *T. harzianum* and *P. fluorescens* alone or in combination with composts (compost P made from agriculture waste and compost A from animal waste) applied in solarized and un-solarized soil was

Table 2 Growth area of bean root rot pathogenic fungi affected with some bio-agents *in Vitro*

Bio-agent	Bean root rot pathogenic fungi			
	<i>R. solani</i>		<i>F. solani</i>	
	Growth area (cm ²)	Reduction %	Growth area (cm ²)	Reduction %
<i>P. fluorescens</i>	5.4	91.5	6.0	90.6
<i>T. harzianum</i>	7.0	89.0	8.0	87.4
Control	63.6	—	63.6	—
LSD at 0.05	19.68	—	22.33	—

studied against bean root rot disease during two growing seasons. The field trail conducted in 60 plots, each 12m² (3m width x 4m length) comprised of 5 rows with 4m length and 20 holes/row, established in naturally heavily infested soil with root rot pathogens *R. solani* and *F. solani*. All plots were irrigated to field capacity and 30 plots were subjected to solarization treatment which carried out by covering with 100 µm thick transparent polyethylene sheets for 8 weeks during July-August 2011, then removed. Maximum and minimum degrees of soil temperature were regularly measured during that period at the soil depths of 10, 20 and 30cm. The average temperature at the three soil depths was calculated at the end of mulching period. The other untreated 30 plots were considered as un solarized one.

After removing the polyethylene sheets the following treatments were applied either in solarized or un-solarized soil:

- (A) Single treatments
- 1- Compost p
 - 2- Compost A
 - 3- *T. harzianum*
 - 4- *P. fluorescens*
- (B) Combined treatments
- 5- Compost p + *T. harzianum*
 - 6- Compost p + *P. fluorescens*
 - 7- Compost A + *T. harzianum*
 - 8- Compost A + *P. fluorescens*
 - 9- Fungicide (Rizolex-T 50% at the rate of 3g/Kg seeds as seed dressing)
 - 10- Untreated control (general control for single and combined treatments)

The antagonistic fungal inoculum *T. harzianum* was grown on PDA medium at

28±1°C until an abundant heavy growth of conidia was evident. Conidia were harvested by scraping the surface of the colonies with a spatula, transferred to sterilized distilled water and filtered through nylon mesh to avoid the mycelium fragments. Spore solution was adjusted with sterile water to give a spore concentration of 10⁶ spores per milliliter. Meanwhile, antagonistic bacteria *P. fluorescens* was grown on Nutrient broth medium and incubated in a rotary shaker at 200 rpm for 24 h at 28±1°C. The bacterial cells were harvested by centrifugation at 6,000 rpm for 10 min, washed twice with 0.05 M phosphate buffer at pH 7.0, and re-suspended in distilled water. The concentrations of bacterial cells in the suspensions were adjusted to 10⁸ cells per milliliter. Concentrations of both bacterial cells and fungal spore suspensions were adjusted with the aid of a haemocytometer slide. The antagonistic bio-agents were individually mixed thoroughly at rate of 1.0 % (v/w) with composts A and P individually before soil application. All Compost treatments were applied at rate of 20 m³/feddan (4200 m²). Compost and/or Bio-agents inocula were incorporated in the top of 20 cm of the soil surface at planting row sites considering relevant treatments. The prepared solution of Bio-agents mixture was also individually incorporated into the same cultivated row site at the rate of 2L/row (4m) after Abdel-Kader (1997). All treatments were applied in Complete Randomized Block Design with three replicates (plots) for each particular treatment. The Bean seeds cv. Giza 3 were sown for two successive seasons (winter and early summer growing seasons September, 2011 and March, 2012) using the same field design plots for the purpose of evaluating the long term effect of applied treatments. Three bean seeds

were sown per hole with 20cm spaces between holes.

Disease assessment

Percentage of root rot incidence at the pre-emergence stage was calculated as the number of absent emerged seedlings in relative to the total number of sown seeds. Meanwhile, percentage of post-emergence root rot was calculated as the number of bean plants showing disease symptoms in relative to the total number of emerged seedlings. Undeveloped, germinated seeds as well as diseased plants were picked up from the soil, washed and sterilized with 3% sodium hypochlorite, then subjected to re-isolation trail in order to identify the causal pathogens. Plant roots showing rot lesions in addition to the visual root rot symptoms on the shoot system were considered diseased plants.

The percentages of pre-emergence root rot incidence was calculated after 20 days from sowing, meanwhile post-emergence bean root rot incidence was recorded periodically every 10 days starting from 20 up to 60 days of plant growth. Determination of accumulated bean yield per m² was calculated. The average percentage of disease incidence and the obtained yield for the two successive growing seasons were calculated and presented.

Statistical analysis

All *in vitro* and *in vivo* experiments were set up in Completely Randomized Design (CRD). The data collected were analyzed using Michigan Statistical Program Version C (MS MSTAT-C program (MSTAT-C, 1988). The means differences were compared by Least Significant Difference test (LSD) value at 0.05 for comparison between means of treatments were used as mentioned by Snedecor and Cochran (1973).

Results

Laboratory tests

Evaluation the antagonistic effect of bio-agents on the growth of bean root-rot fungi was carried out *in vitro*. The antagonistic effect of *T. harzianum* and *P. fluorescens* against the

linear growth of pathogenic fungi *F. solani* and *R. solani* was presented in Table (2). The obtained results indicate that both bio-agents significantly reduced the growth area of pathogenic fungi. The growth area of *R. solani* recorded as 5.4 and 7.0 cm² when grown against the bio-agents *P. fluorescens* and *T. harzianum*, respectively. Meanwhile, *F. solani* growth area recorded as 6.0 and 8.0 cm² when exposed to *P. fluorescens* and *T. harzianum* in the same growth medium. On the other hand, the growth area of both pathogenic fungi recorded 63.6 cm² in growth medium free of bio-agents.

Field experiments

Isolation trails of undeveloped, germinated seeds as well as bean diseased plants revealed that the causal pathogens were *R. solani* (AG4) and *F. solani*. These fungi were identified according to Gilman (1957); Barnett and Hunter (1972). Hunter (1972). Under field conditions, average of maximum and minimum soil temperatures in solarized and un-solarized soil was recorded during solarization period. Results in Table (3) indicate that maximum soil temperatures in solarized soil was increased by 15.0, 14.3 and 13.1°C at depths of 10, 20 and 30cm of soil surface as compared with un-solarized soil. The highest increase in soil temperatures was obtained at solarized soil which recorded 56.5, 51.5 and 46.5°C as maximum soil temperatures at three depths, respectively. Disinfestation of soil of soilborne pathogens and pests has been mainly based on methods of soil fumigation and soil steaming (Baker and Cook 1974; Dawson et al. 1965). However, the report of Katan et al. (1976) in 1976 on the use of solar heating for disinfesting soil of pathogens and pests, now known as soil solarization, attracted the attention of many agriculturalists and is now widely used (Katan et al. 1987). Plant pathogenic fungi are among the most sensitive soilborne organisms to soil solarization, especially species that are unable to grow at temperatures higher than 30° to 33°C; they are categorized as mesophiles. Immediately after soil solarization, the population densities of "total" fungi were reduced by 85 to 90 percent

Table 3 Averages of maximum and minimum soil temperatures at different soil depths in mulched and un-mulched soil during July and August, 2011.

Soil depth (cm)	Mulched soil		Un mulched soil	
	Min. °C	Max. °C	Min. °C	Max. °C
10	40.2	56.5	25.0	41.5
20	37.0	51.5	27.0	37.2
30	35.0	46.5	23.0	33.4
LSD at 0.05	1.82	3.64	2.14	3.27

in different experimental plots. However, population densities of thermotolerant and thermophilic fungi remained relatively high following solarization, and increased to levels higher than present in non-solarized soil (Stapleton and DeVay 1982). Depending on soil depth, maximum temperatures of solarized soil in field areas are commonly between 42° to 55°C at the 5 cm depth and range from 32° to 36°C at the 45 cm depth. Solarized soil under glasshouse conditions or under double layers of transparent PE film, reaches higher temperatures than soil under a single layer of film in the field (Horiuchi 1984; Cenis 1987).

Applied field treatments of *T. harzianum* and *P. fluorescens* alone or in combination with compost in solarized or un-solarized soil were evaluated for their long term effect against bean root rot disease throughout two successive growing seasons (winter and early summer growing seasons). Presented results in Table (4) indicate that all treatments significantly reduced the disease incidence at two seasons. All applied treatments in solarized soil were effective against disease incidence than un-solarized soil. Data also showed that the most pronounced treatments, were the compost A plus *T. harzianum* or *P. fluorescens* in solarized soil which reduced the root rot disease by 73.3 & 86.8 and 70.7 & 85.3 % at pre-, and post-emergence growth stages, followed by combined treatments between compost P and *T. harzianum* or *P. fluorescens* in solarized soil which reduced the root rot disease more than 65.3 and 73.5% for pre-, and post-emergence, in respective order. Meanwhile, single treatments showed moderate effect. Similar trend was also observed in un-solarized soil. As for bean yield the obtained results are presented data in Table (5). Data showed the

influence of *T. harzianum* and *P. fluorescens* alone or in combination with compost on produced yield of bean plants grown in solarized or un-solarized soil. Applied treatments of *T. harzianum* and *P. fluorescens* alone or in combination with compost indicate significant increase of bean yield. Also, applied treatments in solarized soil were more effective in yield increase than un-solarized soil. The highest increase was obtained with combined treatments between compost A and *T. harzianum* or *P. fluorescens* in solarized soil which increased the bean yield by 66.0, 60.0% and 64.4, 56.3% at the two successive growing seasons, respectively. Similarly, combined treatments between compost P and *T. harzianum* or *P. fluorescens* in solarized soil increased the bean yield by 45.0, 46.0% and 42.4, 44.8% at the two successive growing seasons, in respective order. Meanwhile, single treatments applied in solarized soil showed moderate yield increase ranged between 20.0-34.5% and 18.6-32.5% at the two successive growing seasons, respectively. The similar trend was observed in un-solarized soil at all applied treatments. The similar trend was observed in un-solarized soil at all applied treatments.

Discussion

Root rot of faba bean caused by a complex of *F. solani* and *R. solani* is considered among the most deleterious diseases, causing great losses in many parts of the world (Celar 2000; Fillion et al. 2003; Harveson et al. 2005; Wen et al. 2005). Biological control of plant diseases, especially soil-borne plant pathogens, has been the subject of much research in the last two decades. Therefore, biological control of plant pathogens is becoming an important

component of plant disease management practices. In this regard, *Trichoderma harzianum* and *P. fluorescens* are reported to be effective bio-control agents for a number of soil-borne plant pathogens, and also known for their ability to enhance plant growth (Sharon et al. 2001; Rose et al. 2003). In present study results indicate that both bio-agents significantly reduced the growth area of pathogenic fungi under *in vitro* conditions. The highest reduction was obtained with *P. fluorescens* and *T. harzianum* which reduced the growth area by 91.5 & 90.6 and 89.0 & 87.4 % for *F. solani* and *R. solani* respectively. Such results concerning the inhibitory effect of various bacterial and fungal antagonists on soil-borne plant pathogens were reported previously by many investigators (Ragab et al. 1999; El-Mougy 2001).

Soil solarization proved to be an efficiency means for controlling soil-borne pathogens. Several investigators reported the efficacy of soil solarization in reducing the incidence and severity of plant diseases caused by soilborne pathogens (Martyn & Hartz 1986; Greenberger et al. 1987; Abdel-Kader & Ashour 1994). Soil solarization during summer months increases soil temperatures to levels lethal to many soil-borne plant pathogens (Arya 2007). In present study, results indicate that solarization was more effective in reducing the bean root rot disease than un-solarized soil. 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; Sundarum 1986). These are direct affects 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 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. This increase in temperatures at different soil depths could affect the population density of soil microflora including the plant pathogens. This fact was previously recorded by Katan et al. (1976) and Katan (1980), 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. 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 found to be killed at 50°C in only 10 min. as exposure time. In the present study, the recorded soil temperature measured at 10, 20 and 30 cm of soil depths in mulched soil reached average of 56.5, 51.5 and 46.5°C during eight weeks of mulching period. Many researches had been done using the biological control as viable and reliable practice against many soil-borne pathogens in modern agriculture (Adams, 1990; Campbell, 1990). Moreover, the effect of soil solarization combined with the antagonistic microbes or fungicides application to control soilborne pathogens was studied by many workers. Also, Greenberger et al. (1984) studied the efficacy of biological control in solarized soil. 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, Yucel and Cali (1997) 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. The phenomenon of antagonism has received much attention during the last few years. Many successful attempts

Table 4 Bean root rot disease incidence in response to applied treatments different bio-agents and composts in solarized or un-solarized soil during two successive growing seasons

Soil application	Bean root rot incidence %							
	Winter growing season, 2011				Early summer growing season, 2012			
	Solarized soil		Un-solarized soil		Solarized soil		Un-solarized soil	
	Pre- ¹	Post- ²	Pre-	Post-	Pre-	Post-	Pre-	Post-
Single treatment								
Compost p	8.2	12.2	11.3	22.2	9.3	13.4	12.6	24.2
Compost A	7.1	11.5	10.5	16.2	8.6	12.3	11.7	17.3
<i>T. harzianum</i>	7.3	12.3	12.2	14.3	8.3	12.8	13.6	15.7
<i>P. fluorescens</i>	7.5	13.7	11.5	15.5	8.5	14.3	12.8	16.8
Combined treatment								
Compost P + <i>T. harzianum</i>	5.2	8.4	8.5	11.4	7.2	10.4	9.6	13.3
Compost P + <i>P. fluorescens</i>	5.2	9.2	8.5	12.2	6.8	10.3	10.2	14.4
Compost A + <i>T. harzianum</i>	4.3	4.5	6.6	8.6	5.4	6.3	7.2	10.2
Compost A + <i>P. fluorescens</i>	4.4	5.3	6.5	8.2	5.9	7.8	7.6	10.3
Fungicide (Rizolex-T)	5.3	4.5	6.3	8.4	6.8	6.7	8.2	10.7
Control	15.0	34.4	21.6	43.0	17.7	36.6	23.6	44.4
LSD at 0.05 for								
At pre-emergence:	Mulched soil (M)		4.36				3.84	
	Treatment (T)		1.12				1.08	
	Between (M) x(T)		2.87				2.64	
At post-emergence :	Mulched soil (M)							
	Treatment (T)		14.36				11.14	
	Between (M) x(T)		2.14				1.81	
			3.24				3.36	

1: Root rot incidence at pre-emergence growth stage

2: Root rot incidence at post-emergence growth stage

for controlling disease producing plant pathogens were reported. Ranguchander, et al. (1997) determined the efficacy of seed treatment and row application of *T. harzianum* and *T. viride* on control of dry root rot of mungbean caused by *M. phaseolina*. Sclerotial number of the pathogen and root rot incidence were greatly reduced with seed treatment of the antagonists, as compared to row application. These records confirmed the obtained results in the present study. Whereas all applied treatments in solarized soil showed high efficacy for controlling bean root rot disease incidence. The most effective treatments were *T. harzianum* or *P. fluorescens* combined with the compost A or P in solarized soil which reduced the root rot disease incidence at both pre-, and post-emergence growth stages. Furthermore, 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 soilborne micro-organisms (Chen and Katan 1980; Stapleton and De Vay, 1986; Stapleton, et al. 1985). These changes could be on the side of vegetative plant growth and produced yield as a result. In this concern, reduction in disease incidence and increasing obtained yield due to soil solarization alone or combined with other treatments were reported by many investigators (Katan 1980; Osman et al. 1986). Abdel-Kader and Ashour (1994) reported that fungicides combined with soil solarization were more effective in reducing percentage of lupin wilt and increased yield in naturally infested soil with the causal fungus than each treatment alone. Moreover, biological treatment in solarized soil gave good effect, as control measure, for soilborne plant pathogens beside beneficial side effects on plant growth and obtained yield (Abdel-Kader 1997; Abdel-Kader & Ashour 1999). They reported an

Table 5 Bean yield at different bio-agents and composts in solarized or un-solarized soil during two successive growing seasons

Soil application	Bean yield kg / feddan (4200m ²)							
	Winter growing season, 2011				Early summer growing season, 2012			
	Solarized soil		Un-solarized soil		Solarized soil		Un-solarized soil	
	yield	Increase %	yield	Increase %	yield	Increase %	yield	Increase %
Single treatment								
Compost p	1300	30.0	1050	31.2	1238	25.0	988	25.8
Compost A	1345	34.5	1100	37.5	1312	32.5	1058	34.7
<i>T. harzianum</i>	1250	25.0	1070	33.7	1189	20.1	1034	31.7
<i>P. fluorescens</i>	1200	20.0	1000	25.0	1175	18.6	975	24.2
Combined treatment								
Compost P + <i>T. harzianum</i>	1450	45.0	1165	45.6	1410	42.4	1127	43.5
Compost P + <i>P. fluorescens</i>	1460	46.0	1120	40.0	1434	44.8	1095	39.7
Compost A + <i>T. harzianum</i>	1660	66.0	1310	63.7	1628	64.4	1288	64.0
Compost A + <i>P. fluorescens</i>	1600	60.0	1275	59.3	1548	56.3	1238	57.7
Fungicide (Rizolex-T)	1400	40.0	1150	43.7	1376	38.9	1094	39.3
Control	1000	--	800	--	990	--	785	--
LSD at 0.05 for								
Mulched soil (M)			34.12				31.24	
Treatment (T)			18.32				14.62	
Between (M) x(T)			26.42				23.41	

announced reduction in root rot incidence of bean and cowpea, caused by the pathogens *R. solani* and *F. solani*, was achieved using the antagonists *T. harzianum* as soil drench either in solarized or un-solarized soil. Similar results were also reported by Ragab et al. (1999) and El-Mougy (2001) against root rot disease of pea and bean plants.

Conclusion

The obtained results in the present study indicate that, solarization and biological control are considered as non-chemical control methods which have advantage and limitation. Therefore, application of biological agents as soil application or seed dressing, in either solarized or un-solarized soil, could be used as an effective and unhazard applicable technique for controlling soil-borne plant pathogens 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 soil-borne pathogens, especially these caused root rot diseases. The technique

evaluated in the present study could be recommended in light of the results obtained. The use of combined treatment of compost and bio-agents could be considered a safe, cheap and easily applied bio-control method to be used against soil-borne plant pathogens, particularly for organic farmers, for avoiding environmental pollution.

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