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Control of Root-Rot of Green Bean with Composted Rice Straw Fortified with *Trichoderma harzianum*

Lubna S. Nawar

Department of Biology, Faculyt of Science, Abd El-Aziz University, Geddah, Saudi Arabia

Abstract: *Rhizoctonia solani* Kuhn causes damping-off and root-rot diseases of a wide range hosts including green beans. *R. solani* was the most aggressive and most frequently encountered pathogen isolated from roots of root-rotted green beans follwed by *Fusarium solani*. This research evaluated the suppressive effects of rice straw compost fortified with *T. harzianum* on damping-off of green beans and plant growth. The microbial composition of the compost-amended soil was also determined. The *in-vitro* studies indicated that members of *T. harzianum* or *T. viride* were the most antagonistic fungus against *R. solani*. Fungi isolated from soil amended with compost 4 weeks before sowing were more antagonistic to *R. solani* than those isolated from soil applied before this time. The inhibitory activities of the compost-inhabiting microbes might partly be responsible for the efficacy of compost in reducing root-rot disease of green bean. In pot experiment, the population density of bacteria in soil infested with *R. solani* and amended with compost fortified with *T. harzianum* were higher than in infested soil alone or with compost. On the other hand, fortified compost with *T. harzianum* applied to the infested soil greatly reduced the total fungal count reaching their smallest population after 4 weeks from treatment. Application of rice straw compost fortified with *T. harzianum* to soil infested with *R. solani* reduced the disease severity to the maximum values and also promoted plant height, fresh and dry weights. Generally, composts might be used deliver or fortify bio-control agents as, they may invigorate their proliferation, increase their efficacy against soil borne pathogens and improve soil fertility.

Key words: Fortified compost · *R. solani* · *T. harzianum* · root-rot disease · green bean · antagonism

INTRODUCTION

Rhizoctonia solani Kuhn is a soil borne fungal pathogen that attacks crops worldwide [1] causing huge losses to growers especially to green bean [2, 3]. The fungus causes damping-off of young plants seeded directly and attacks the stem below and above the soil surface. The plants die soon after infection. On the older plants, the pathogen causes, reddish-brown cankers extended longitudinally along the woody stem near the soil surface. The plant at this later stage may show little indication of disease, except the yields may be reduced considerably [3]

Control of the pathogen is currently limited to the use of long rotation [4], soil solarization [5] and prophylactic fungicide [6]. In the research for alternatives to soil chemical treatments, biological control may be useful tool [7-9]. Selected microbial control agents are active bioprotectores and have been widly used in biocontrol of *R. solani* in different agricultural crops such as soybean [10], cotton [11], oilseed rape [12] and chickpea [13].

Fungi from *Trichoderma* genus are among the biological control agents of *R. solani* [14-16]

Compost made of agricultural and industrial wastes have been widly used as soil amendments [17, 18]. Composts induced suppression of soil borne pathogen through biological mechanisms [19, 20]. Another important characteristic is their role in increasing soil nutrient availability and in plant growth stimulation [19-21]. Rice straw composts that are produced through the action of some microorganisms on rice straw organic matter, also have a great potential as plant growing media [20-23].

The objective of the present study were to investigate the efficiency of compost alone or fortified with an antagonistic agent *T. harzianum* and their time of application in the suppression of root rot disease caused by *R. solani*. The effect of different treatments on soil microflora was also studied.

Corresponding Author: Dr. Lubna S. Nawar, Department of Biology, Faculyt of Science, Abd El-Aziz University, Geddah, Saudi Arabia

MATERIALS AND METHODS

Isolation of fungal pathogens: Green bean plants showing symptoms of root-rot infections were obtained from region beside north of Jeddah, Saudi Arabia and brought to the laboratory. The roots and stems of the infected plants were rinsed in tap water and the necrotic portions were excised and cut into 2 mm pieces, surface sterilized with 2.5% sodium hypochlorite (Na OCl) for one minute and rinsed in 4 successive changes of sterile distilled water. These pieces were then plated on Potato Dextrose Agar (PDA) medium and incubated for 7 days at 28°C under 12-h photoperiod.

The growing fungal colonies were transferred to new PDA plates and pathogens were identified using cultural and morphological features with reference of Gilman [24] and Barnett and Hunter [25], while the confirmatory identification was made by the Plant Pathology Department, National Research Centre, Cairo Egypt.

Pathogenicity test: Pathogenicity tests were carried out by sowing surface sterilized green bean seeds (cv. Bollita with 98% germination) in pasteurized soil infested with each isolate of fungal pathogen isolated from green beans. Pots were kept in a greenhouse at 22°C under 12-h periods of fluorescent light. The pathogen was reisolated from symptomathic seedlings by superficial disinfection with 2% Na OCl and plating on PDA medium. Inocula for pathogenicity test and for bioassay was obtained by growing each fungal isolate on PDA medium and multiplied on sterilized oat grains as described previously [20].

Pasteurization of the soil was carried out by autoclaving it at 121°C for one hour. Twenty seeds of green bean were sown in each pot and the pre and post-emergence damping-off were recorded 15 and 60 days after planting respectively. Plant heights as well as their fresh and dry weights were estimated at the maturity stage.

Isolation of fungi and bacteria from soil amended with rice straw compost: A one year old rice straw compost was used in this study. Chemical properties of the compost were analyzed by soil microbiology Department,NRC of Egypt and are summarized in Table 1.

Plastic pots (25-cm-diam) filled with 5 kg of loamy soil was amended with 50 g rice straw compost and mixed thoroughly and watered every other day. The pots were allowed to decompose for four weeks. Soil samples were taken weekly during the decomposition for microbiological analysis. Composted soil samples (10 g) placed in Erlenmeyer flask containing 90 ml of deionized water were placed in a shaker at 70 rpm for 1 h. Serial 10-fold dilutions were prepared and dilutions of 1 ml were incubated on plates with 10 ml of Martins medium [26] amended with 100 ppm streptomycin sulphate and penicillin antibiotics for counting fungi and soil extract agar medium [27] for bacterial count. The bacteria developed were counted 3 days after incubation at 28°C and the fungi were counted after 7 days incubation at 25°C. The colony counts were converted to colony forming units (cfu per gram dry weight of soil).

Table 1: Chemical analysis of rice straw compost

Constituents	Value
Organic matter	61.20 (%)
Organic carbon	35.50 (%)
Total nitrogen	1.95 (%)
C/N ratio	18.20
Phosphorus	1.35 (%)
Potassium	0.88 (%)
pH	7.67
Ash content	18.20 (%)

Antagonism between fungi and bacteria from compost-amended soil and *R. solani*.: Interaction between each isolated microorganism and *R. solani* were observed in cultures according to method of Rivera *et al.* [20]. Petri dishes were divided into two halves by marking with a permanent marker on under sides. Discs (0.5 cm-diam.) of fungal cultures (*R. solani* and test fungi) from seven days old cultures on PDA were placed simultaneously at opposite sites of the plate. Bacterial cultures were inoculated in the form of stripes of 2 cm made near the edge of the plates,whereas the other side of the plate was inoculated with *R. solani* discs. All plates were incubated at 28°C and examined for the presence of an inhibition zone. Also, the percentage of reduction in the hyphal growth was calculated according to Topps and Wain [28] formula as follow:

$$\text{Percentage of reduction} = [(A-B)/A] \times 100$$

A = Diameter of the control hyphal growth.
B = Diameter of the treated hyphal growth.

Greenhouse experiments: Pot experiment was carried out to evaluate the role of compost fortified with *T. harzianum* Refai obtained from Plant Pathology Dept., NRC of Egypt gainst *R. solani* the causal organism of root-rot

disease. Pots containing soil (5 kg) somewhat wet (about 60% water holding capacity) were inoculated with a propagules of *R. solani* at a rate of 50 g/ pot, 2 days before cultivation to ensure the distribution of the inocula. Pots were mixed with 1% compost non-fortified or fortified with *T. harzianum*.

The microbial changes induced by adding compost or compost fortified with *T. harzianum* to the soil infested with *R. solani* were investigated before sowing. Soil samples were taken weekly during 4 weeks before sowing seeds for microbiological analysis on growth media, as described above. Twenty surface sterilized seeds (cv. Bollita) were planted after soil inoculation and thinned later to five seedlings/ pot. A set of four pots was used for every treatment. Treatments included:-

- Un-inoculated soil (control).
- Inoculated soil with *R. solani* (control).
- Applied soil with compost alon (control).
- Inoculated soil with *T. harzianum* (control).
- Inoculated soil with *R. solani* + compost.
- Inoculated soil with *R. solani* + *T. harzianum*.
- Inoculated soil with *R. solani* + compost + *T. harzianum*
- Inoculated soil with *T. harzianum* + compost.

Pre-and post emergence damping-off was recorded as mentioned before in the pathogenicity test. At the end of the experimental period plant height, fresh and dry weights of the survival plants were determined. The obtained data were statistically analyzed according to Snedecore and Cochran [29].

RESULTS AND DISCUSSIONS

Root-rot pathogens of green bean: Isolation from root-rotted seedlings and plants revealed the association of one or more of the following 8 fungal species, i.e., *Alternaria tenuis, Aspergillus flavus, A. niger, A. tamarii, Cephalosporium maydes, Fusarium moniliforme, F. solani* and *R. solani*. *R. solani* in particular was more frequent than any of the other fungi. These fungi were previously reported to be associated with root-rot of legume plants in other countries [22, 30, 31]

The green bean plants produced in pasteurized soil in the absence of pathogens showed no symptoms of root-rot damping-off. Isolates of *Fusarium* and *Rhizoctonia solani* were found more or less able to attack green beans at any stages of plant growth (Table 2). Green bean was highly vulnerable to attack by the all

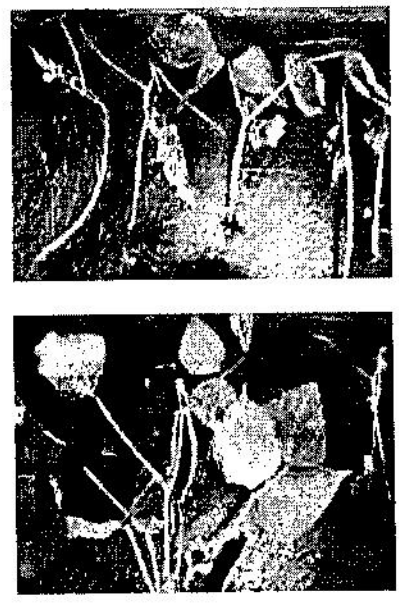

Fig. 1: Green bean plants showing root-rot symptoms incited by *R. solani* and control 45 days after sowing in infested soil

three isolates of *R. solani*. The isolate no.6 of *R. solani* caused 90% post emergence damping-off. The other two isolates of *R. solani* also caused 50.0 and 42.5% post emergence damping-off.

Reisolation from diseased roots yielded only the same fungus used for the artificial infestation of the soil.

Greenbean plants which survived in infected soil never attained the normal growth either in height or fresh and dry weights (Table 2 and Fig. 1). The plant height which survived in soil infested with the fungal isolates tested averaged only between 13.00 and 45.0 cm than that grown in un-infested control soil (48 cm).

The role of *R. solani* was prominent in both the survival, i.e., the survived plants attained the least growth in height, fresh and dry weights when compared with any other fungal treatment. *R. solani* has long been known to be the main organism causing root-rot of green bean plants causing huge losses to growers [1-3]. *R. solani* was not only the most aggressive pathogen but also, as mentioned before it was the most frequently encountered fungus upon isolation of fungi from roots of root-rotted green bean. For this reasons, *R. solani* was used in all further studies.

Antagonism between compost microorganisms and *R. solani*: Numbers and types of fungi and bacteria isolated

Table 2: Pathogenicity of isolates representing fungal species associated with root-rot of green bean and their effect on morphogenesis on plant growth

		Damping-off (%)		Morphogenesis of survived plants		
Tested fungi	Isolate No.	Pre	Post	Shoot length (mm)	Fresh weight (g)	Dry weight (mg)
Alternaria tenuis	1	9.00	10.00	45.00	13.16	941.0
Cephalosporium maydes	2	21.00	20.00	42.00	14.00	992.3
Fusarium moniliforme	3	6.00	17.50	41.25	13.38	962.5
F. solani	4	61.00	27.50	24.00	6.74	639.8
F. solani	5	69.00	25.00	25.50	7.52	735.7
Rhizoctonia solani	6	74.00	50.00	14.25	4.43	356.0
R. solani	7	81.50	90.0	13.00	1.48	239.0
R. solani	8	70.00	42.50	16.50	2.63	432.8
Un-infested (control)	-	0.00	0.00	48.00	15.26	1904.8
LSD at 5%		13.58	20.40	3.50	1.58	99.37

Four replicated pots each sown with 20 green bean seeds were used

Table 3: *In vitro* antagonism between different isolates of soil fungi isolated from soil fortified with compost and the root-rot pathogen *R. solani*

	Time of sample before sowing							
	First week		Second week		Third week		Fourth week	
Isolated fungi	1	2	1	2	1	2	1	2
Alternaria tenuis	0.0	22.22	-	-	-	-	-	-
Aspergillus clavatus-1	-	-	-	-	-	-	2.0	13.33
Aspergillus clavatus-2	-	-	-	-	16.0	17.78	-	-
A. humicola	0.0	22.22	-	-	-	-	-	-
A.niger-1	0.0	16.67	-	-	28.0	31.11	-	-
A.niger-2	-	-	-	-	18.0	20.00	-	-
A.niger-3	-	-	-	-	0.0	11.11	-	-
A. ochraceus	10.0	15.56	-	-	-	-	-	-
A. rubber-1	-	-	-	-	-	-	0.0	22.22
A. rubber-2	-	-	-	-	-	-	0.0	20.00
A. rubber-3	-	-	-	-	-	-	0.0	11.11
A. tamarii-1	4.0	13.33	0.0	11.11	-	-	-	-
A. tamarii-2	10.0	11.11	26.0	28.89	-	-	-	-
A. terreus-1	-	-	18.0	20.00	-	-	-	-
A. terreus-2	-	-	26.0	28.89	-	-	-	-
Cephalosporium sp.	11.0	12.22	-	-	-	-	-	-
Fusarium dimerum	0.0	11.11	-	-	8.0	20.00	-	-
F. oxysporum	0.0	11.11	-	-	8.0	20.0	-	-
F. solani-1	6.0	17.78	2.0	11.11	28.0	28.0	8.0	8.89
F. solani-2	-	-	8.0	8.89	-	-	-	-
F. solani-3	-	-	0.0	11.11	-	-	-	-
Gliocladium sp.-1	-	-	28.00	31.11	0.0	31.11	-	-
Gliocladium sp.-2	-	-	-	-	27.0	30.00	-	-
Mucor mucedo	24.0	26.67	20.0	54.44	0.0	20.00		
Paecilomyces sp.	0.0	26.67	-	-	-	-	-	-
Penicillium sp.	10.0	11.11	-	-	-	-	-	-
Rhizopus nigricans	9.0	10.00	-	-	-	-	-	-
Stymphylium sp.	9.0	10.00	-	-	-	-	-	-
Trichoderma harzianum-1	0.0	86.67	40.0	42.22	86.67	31.11	24.0	80.0
Trichoderma harzianum-2	-	-	-	-	85.56	60.0	26.0	84.44
T. viridi	-	-	30.0	41.11	-	-	-	-
Un-known-1	20.0	22.22	10.0	22.22	-	-	-	-
Un-known-2	-	-	10.0	22.22	-	-	-	-
Un-known-3	-	-	-	-	-	-	25.0	27.78
Un-known-4	-	-	-	-	-	-	6.0	6.67

1 = Inhibition zone (mm), 2 = Redu--ction (%), *PDA plates were used in triplicates for dual cultures assays, - = not isolated or detected

Table 4: *In vitro* antagonism between different isolates of soil bacteria isolated from soil fortified with compost and the root-rot pathogen *R. solani*

Time of sample before sowing	No.of tested bacteria	No. of positive isolates	Diameter of *R. solani* colony (mm)	Inhibition (%)	Zone of inhibition (mm)
First week	22	5 (*Bacillus* spp.)	(1)-54	40.00	10.00
			(2)-40	55.56	10.00
			(3)-25	72.22	20.00
			(4)-25	72.22	35.00
			(5)-55	38.89	15.00
Second week	21	5 (*Bacillus* spp.)	(1)-50	44.00	10.00
			(2)-50	44.44	8.00
			(3)-60	33.33	7.00
			(4)-27	70.00	38.00
			(5)-30	66.67	39.00
Third week	10	5 (*Bacillus* spp.)	(1)-35	61.11	5.00
			(2)-48	46.67	8.00
Fourth week	10	5 (*Bacillus* spp.)	(1)-48	46.67	0.00
			(2)-82	8.89	0.00
			(3)-84	6.67	0.00
			(4)-58	35.56	0.00

*PDA plates were used in triplicates for dual cultures assays

from the compost added to the soil were recorded weekly during 4 weeks. The antagonistic action of such representative isolates on *R. solani* was recorded using the dual plate culture technique.

Fungi: The tested isolates were differed in their antagonistic action against *R. solani* (Table 3). The data revealed that isolates of *Trichoderma* spp. were accounted and isolated from samples incubated for four weeks after the amendment incorporation. Members of *T. harzianum* or *T. viride* were found to be the most potent as antagonistic organisms to *R. solani*, based on the reduction in growth area of pathogen, some were stronger than others. Fungi from soil applied with compost 4 weeks before sowing were more antagonistic than those from soil applied before this time.

These results give further supported to the idea that compost are potent enough to afford propitious media for the propagation of bio-agent and production of antagonistic principles against certain soil borne root pathogens. Moreover, rice straw might have served as food base for some *Trichoderma* spp. in the soil.

Isolates of *Gliocladium* spp. and *Aspergillus niger* were found to follow *Trichoderma* spp. inducing a very pronounced inhibition zone of 28 mm. This phenomenon was probably correlated with differences in levels of hydrolytic enzymes produced by each species or isolate,when they attacked mycelium of *R. solani* [32]. *Trichoderma* sp. was assumed to attack the pathogen's mycelium by dissolving cell walls in certain locations followed by hyphae penetration, then producing other extracellular enzymes, lipase, protease and β-1,3 glucanase to continue the lysis process.

Bacteria: All bacterial isolates from soil amended with compost in samples of the four weeks were classified as *Bacillus spp* (Table 4). Among the tested bacteria, isolates (no. 3 and 4) of the first week and (no. 4) of the second week were found to be the most potent bacteria against *R. solani* as shown in Fig. 2.

Isolation provided an interesting member of compost microorganisms and *in-vitro* tests added evidence for specific forms of pathogen suppression [20].

The microbial changes before sowing induced by adding compost or compost fortified by *T. harzianum* to the infested soil with *R. solani* were investigated.

Effect of compost fortified with *T. harzianum* on microbial density

Effect on total bacterial count: Total number of bacteria in infested or non-infested soil was increased generally as the time of application before sowing increased (Table 5). The average number of bacteria in non-infested soil (control) was much lower than all the other treatments.

Table 5 Total bacterial count from soil infested with *R. solani* and amended with compost fortified with *T. harzianum* four weeks before sowing (cfu x 10^3/g dry weight)

	Weeks before sowing				
Soil treatment	1	2	3	4	Mean
Un-infested soil (control)	12.69	100.66	112.81	155.84	95.50
Infested with *R.solani*	403.76	342.63	449.51	445.25	320.29
Compost	885.71	734.10	2279.59	3598.48	2124.47
T. harzianum	285.06	690.02	215.18	250.71	360.24
R.solani + compost	971.46	773.40	859.10	1367.18	992.785
R.solani +*T. harzianum*	1145.66	806.45	1268.20	7142.85	2590.79
R.solani+ compost+ *T. harzianum*	1208.45	2884.28	4827.58	3366.03	3046.59
T. harzianum+compost	1168.61	4501.60	2535.65	2614.37	2705.06

*Counts of bacteria were on soil extract agar medium incubated at 28°C for 7 days

Fig. 2: *In vitro* inhibition of *R. solani* by compost bacteria isolates

It is worthy to mention that the population density of bacteria in infested soil with *R. solani* and applied with compost fortified with *T. harzianum* were higher than in infested soil alone or in combination with compost. The numbers of bacteria were increased by adding compost to soil alone or soil infested with *R.solani* during all periods before sowing. This, however indicated that the use of compost furnished a proper substrate for growing bacteria. Besides, bacteria were established and may have secreted different metabolites such as antibiotics, siderophore and growth regulators in the growth medium containing compost.

Effect on total fungal count: Total fungal count in soil infested with *R. solani* was higher than in un-infested control treatment during all periods before sowing (Table 6). Application of compost to soil un-infested or infested with *R. solani* increased the fungal population reaching 3674.24 and 2851.56 cfu x 10^3 dry weight respectively after 4 weeks before sowing. On the other hand, fortified compost with *T. harzianum* applied to infested soil greatly reduced the total fungal count reaching their smallest population after 4 weeks from treatment reaching 112.82 x 10^3 dry weight. It is possible that *T. harzianum* may have been inhibitory toward other fungal spp. The breakdown of organic wastes in a formulated culture medium may have direct harmful effects on soilborne pathogens [23].

Effect of compost fortified with *T. harzianum* on disease incidence and plant growth

Root-rot disease incidence: There was no natural infection of root-rot pathogen and other soil borne plant pathogens in the un-infested control soil or un-infested soil amended with compost or *T. harzianum* alone or combine. All compost and *T. harzianum* treatments applied to soil infested with *R. solani* at different time before sowing significantly reduced the percentage of pre-and post-emergence incidence of damping-off than the infested control treatment (Table 7). The damping-off

Table 6: Total fungal count from soil infested with *R. solani* and amended with compost fortified with *T. harzianum* four weeks before sowing (cfu x 10^3/g dry weight)

	Weeks before sowing				
Soil treatment	1	2	3	4	Mean
Un-infested soil (control)	216.93	167.22	74.20	81.24	134.89
Infested with *R.solani*	419.25	968.99	968.18	1021.89	844.57
Compost	780.95	1657.03	1203.31	3674.24	1828.88
T. harzianum	136.83	403.39	113.92	50.14	176.07
R.solani + compost	394.02	915.88	1400.34	2851.34	1390.45
R solani +*T. harzianum*	376.42	1774.19	625.00	2389.16	1291.19
R.solani + compost + *T. harzianum*	412.89	1208.98	643.67	112.82	594.59
T. harzianum +compost	1043.40	1173.63	2533.65	2287.58	1759.56

*Counts of fungi were on modified Martin's agar medium incubated at 28°C for 7 days

Table 7: Effect of different compost and T.harzianum at different times before sowin on root-rot disease incidence of green bean

		Time of treatment before sowing (week)				
Soil treatment	Damping-off	1	2	3	4	Mean
Un-infested soil (control)	Pre	0.00	0.00	0.00	0.00	0.00
	Post	0.00	0.00	0.00	0.00	0.00
Infested with R.solani	Pre	73.33	77.33	84.00	84.00	79.67
	Post	82.14	100.00	91.67	91.67	91.37
Compost	Pre	0.00	0.00	0.00	0.00	0.00
	Post	0.00	0.00	0.00	0.00	0.00
T. harzianum	Pre	0.00	0.00	0.00	0.00	0.00
	Post	0.00	0.00	0.00	0.00	0.00
R.solani + compost	Pre	21.33	16.67	20.00	8.00	16.50
	Post	43.33	50.00	23.33	20.00	34.17
R.solani +T. harzianum	Pre	22.67	20.00	17.33	12.00	18.00
	Post	50.00	50.00	43.33	40.00	45.83
R.solani+ compost+ T. harzianum	Pre	9.33	10.00	8.00	9.33	9.17
	Post	33.33	30.00	26.67	20.00	27.50
T. harzianum+compost	Pre	0.00	0.00	0.00	0.00	0.00
	Post	0.00	0.00	0.00	0.00	0.00
Mean of time	Pre	15.83	15.50	16.17	14.17	
	Post	26.10	28.75	23.13	21.46	
LSD at 5% for treatments	Pre	3.25				
	Post	5.05				
LSD at 5% for time	Pre	N.S				
	Post	3.57				
LSD at 5% for interaction	Pre	6.49				
	Post	10.09				

incidence was severe in the *R. solani*-infested control treatment reaching 84.00 (pre-) and 91.67% (post-) after 4 weeks of application.

Effect of compost: Amendment of 1% rice straw compost to the *R. solani* infested soil significantly suppressed damping-off depending on the time of application before sowing (Table 7). The incidence and severity were reduced reaching 8.00% for pre-emergence and 20.0% for post emergence damping-off with the compost treatment added 4 weeks before sowing. Whereas, compost used before a short period before sowing (one week) also reduced the disease incidence recorded 21.33 and 43.33% respectively. The suppressiveness of soil amended with composted rice straw and infested with *R. solani* varies with age of the compost and the presence of microbial agents [23, 33, 34].

Table 8: Effect of compost and *T. horzianum* on growth of green bean plants 4 weeks before sowing

		Time of treatment before sowing (week)				
Soil treatment	Emergence	1	2	3	4	Mean
Un-infested soil (control)	Plant height (cm)	48.85	40.93	42.10	48.70	45.14
	Fresh weight (g)	14.36	13.83	14.09	15.62	14.48
	Dry weight (g)	5.31	4.14	3.58	4.95	4.50
Infested with R.solani	Plant height (cm)	12.87	12.32	13.47	12.33	12.75
	Fresh weight (g)	2.03	1.92	1.76	1.23	1.74
	Dry weight (g)	0.75	0.53	0.60	0.55	0.61
Compost	Plant height (cm)	42.41	43.00	45.47	50.97	45.46
	Fresh weight (g)	13.90	13.51	14.52	16.82	14.69
	Dry weight (g)	3.84	3.94	4.73	3.69	4.05
T. harzianum	Plant height (cm)	49.61	37.95	42.30	53.23	45.77
	Fresh weight (g)	14.30	12.23	13.88	16.36	14.19
	Dry weight (g)	3.38	3.52	4.63	4.10	3.91
R.solani + compost	Plant height (cm)	33.57	34.41	39.76	34.68	35.60
	Fresh weight (g)	8.25	8.46	8.74	10.08	8.88
	Dry weight (g)	1.40	1.50	1.82	2.53	1.81
R.solani +T. harzianum	Plant height (cm)	27.12	30.20	31.73	34.66	30.92
	Fresh weight (g)	7.92	8.29	11.43	11.53	9.79
	Dry weight (g)	1.28	1.36	2.94	3.33	2.23
R.solani+ compost+ T. harzianum	Plant height (cm)	23.94	25.43	28.06	25.00	25.61
	Fresh weight (g)	9.79	9.45	9.13	20.59	12.24
	Dry weight (g)	3.52	3.70	2.78	3.18	3.30
T. harzianum + compost	Plant height (cm)	51.17	43.34	44.63	49.67	47.20
	Fresh weight (g)	15.56	14.00	14.77	19.26	15.90
	Dry weight (g)	4.94	4.85	5.58	5.54	5.23
Mean of time	Plant height (cm)	36.19	33.45	35.94	38.65	
	Fresh weight (g)	10.76	10.21	11.04	13.94	
	Dry weight (g)	3.05	2.94	3.33	3.49	
L.S.D at 5% for treatments	Plant height				2.49	
	Fresh weight				1.45	
	Dry weight				0.41	
L.S.D at 5% for time	Plant height				1.76	
	Fresh weight				1.03	
	Dry weight				0.29	
L.S.D at 5% for interaction	Plant height				4.97	
	Fresh weight				2.90	
	Dry weight				0.82	

Effect of compost fortified with *T. harzianum*: There was significant interaction between *T. harzianum* and the compost applied at different period before sowing. The disease severity was significantly reduced by the rice straw compost fortified with *T. harzianum* than *R. solani* infested alone (Table 7). The disease suppressive effect of the fortified compost was also better than compost or *T. harzianum* treatment alone. Similar results were noted by De Ceuster and Hoitink [19], they reported that a composted pine bark mix fortified with *T. hamatum* has been very effective for control of Fusarium wilt of cyclamen and Rhizoctonia disease.

The low incidence of root-rot disease of green bean in soil applied with compost and fortified with *T. harzianum* suggests that the growth substrate is conducive for rapide proliferation of biocontrol agent.

Effect on plant growth: Regarding the morphogenesis of the survived plants as represented by shoot length, fresh and dry weights, data in Table 8 reveal that plants of all control treatments applied to soil at different period before sowing, grew better than plants of the uninfested (control) and infested with *R. solani* alone.

Effect of compost: Addition of compost to soil at different period before sowing significantly increased plant height, fresh and dry weights (Table 8). Amendment of soil with compost to infested soil with *R. solani* also significantly increased the growth parameters than plants of the infested or non-infested soil. Rivera *et al.* [20] reported that vermicompost incorporation at 20% rate reduced the incidence of Rhizoctonia root-rot and crown rot and also promote tomato seedlings growth (measured as fresh weight).

Effect of compost fortified with *T. harzianum*: Fortified compost with biocontrol agent, *T. harzianum* positively affected plant growth in comparison to infested and non-infested soil with *R. solani*. Its evident that the above treatments resulted in a significant increase in plant height, fresh and dry weights/ plant than plant of the control or plants of the infested soil with *R. solani* only or in combination with compost or *T. harzianum*.

Moreover, soil applied 4 weeks before sowing with compost and fortified with *T. harzianum* was more effective generally than any other treatment, increasing plant growth.

General conclusion: Generally, composts might be used to deliver or fortify bio-control agents as they may act as substrate for them and invigorate their proliferation. Composts may also increase the efficacy of bio-control agents against soilborne pathogens and at the same time provide nutrients to plants and improve soil health in general.

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