Egypt. J. Phytopathol., Vol. 41, No. 1, pp. 27-41 (2013)

Role of Endomycorrhizae on Controlling Stem- and Root-Rot of Pepper Caused by *Sclerotium rolfsii*

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This study was designed to investigate the effect of inoculation time with vesicular arbuscular mycorrhizal (VAM) fungi, *Glomus* spp., on the interaction between root-rot and stem-rot of pepper caused by *Sclerotium rolfsii* Sacc. as well as its growth. The results indicated that addition of *Glomus* spp. significantly increased the shoot and root fresh and dry weight with significant decrease to the disease severity (59-89%). Effect of the mycorrhizal inoculation using five species of *Glomus* by two different inoculation treatments on incidence of Sclerotium stem-rot as well as crop parameters of pepper plants inoculated with the tested fungus was investigated. Generally, mycorrhizal inoculation increased pepper shoot and root fresh and dry weight compared with uninoculated plants. Meanwhile, seedlings arose from seeds treated with *Glomus* spp. increased growth parameters and yield. *G. coronatum* and *G. luteum* were the best mycorrhizae to increase crop parameters. On the other hand, *G. etunicatum, G. diaphanum* and *G. luteum* were the best to protect pepper plants against *S. rolfsii*.

Keywords: Biological control, Endomycorrhizae, pepper, root-rot, stem-rot and *Sclerotium rolfsii*.

Pepper (*Capsicum annum* L.) plant is considered as one of the important vegetable crops in Egypt. Pepper is one of the vegetables with shallow root in need to abundant nutrient elements; the shallow root system does not allow the absorption of nutrient elements in the deep part of soil (Simsek *et al*., 1998). The positive responses of mycorrhizal application in both open field production and seedling growing (Simsek *et al*., 1998 and Ikiz *et al*., 2009) have given an idea that the arbuscular mycorrhizal (AM) fungi could affect the plant development positively. Haas *et al*. (1987) reported that pepper yield increased with mycorrhizal inoculation compared with uninoculated ones. The researches in the last years indicate that symbiosis of some kinds of mycorrhizae with plant root facilitates the absorption of nutrient elements such as P and Zn. The best known advantage of arbuscular mycorrhizal (AM) fungi inoculation is the increase of the plant growth and increase of fruit yield. This positive effect is especially due to enhancing uptake of nutrients. Sreenivasa *et al*. (1993) observed that inoculation of chili (*Capsicum annum* L.) with mycorrhizal fungi *Glomus fasciculatum* increased fruit yield, shoot and phosphorus concentration compared with controls. Also they found that inoculation with *G. macrocarpum* had greater effect than inoculation with *G. fasciculatum*.

Sclerotium rolfsii Sacc. is an important destructive pathogen on more than 500 plant species (Punja and Rahe, 1992) including pepper, which causes a considerable economic loss especially in newly reclaimed desert land (Sherf and Macnab, 1986). The Sclerotium stem- rot occurs regularly in all areas. The disease is wide spread and causes serious losses in Egypt. Kulkarni *et al.* (1997) reported that mycorrhizal fungi, *i.e*. *G. fasciculatum*, *Gigaspora margarita*, *Acaulospora laevis* and *Sclerocystis dussi* reduced the infection by the pathogenic fungus *S. rolfsii*. *G. fasciculatum* was the most effective and mycorrhizae worked best when they were added individually. Sreenivasa (1997) investigated the influence of *Glomus macrocarpum* on the infection by *S. rolfsii* on three *Capsicum annum* varieties. He found that the percentage of sclerotial bodies was significantly reduced in plants inoculated with *G. macrocarpum*.

This study aimed to investigate the differentiation of five different mycorrhizal species (*Glomus* spp.) and the effect of the different inoculation treatments (at sowing and at transplanting) on disease severity, plant growth of pepper plants, the interaction between *Glomus* spp. and the pathogen *S. rolfsii* on pepper growth and yield.

Materials and Methods

Extraction, purification and preservation of vesicular arbuscular mycorrhizal (VAM) fungi:

Vesicular arbuscular mycorrhizal fungi were collected from the rhizosphere of various plants, *i.e.* maize, pepper, potato and peanut grown in three governorates, namely; Beni Suef, Ismailia and Menofiya. Sample of rhizosphere soil (100g) was carefully collected from roots of healthy plants and placed in polyethylene bag. Extraction of VAM propagules from soil was carried out under laboratory conditions as soon as possible using wet – sieving and decanting technique described by Gerdman and Nicolson (1963), Gerdman and Trappe (1974) and Trappe (1982). *Sclerotium rolfsii* isolates were obtained from Mycol. Res. & Plant Dis. Survey Dept., Plant Pathol. Res. Inst., A.R.C., Giza, Egypt. Mycorrhizal spores were breed as many as single spores inoculated (on maize root), where VAM propagation was multiplied and maintained in open pot cultures of Sudan grass as a host on a vivo medium.

Effect of Glomus spp*. on the rate of pepper seed germination:*

Thirty pepper seeds (cv. Inhatem M) were sown in sterilized pots (50-cm- diam.) contained sterilized soil infested with any of five isolates of *Glomus* spp., *i.e. G. etunicatum*, *G. mosseae, G. diaphanum*, *G. luteum* and *G. coronatum*. About 2500 spores/pot were counted and added to 50g mixture of Sudan grass and soil infested previously with *Glomus* spp. Inoculum free pots sown with pepper seeds were left as control. The growth of pepper seedlings and percentages of emerged seedlings were recorded in each treatment, 30 days after sowing.

Effect of Glomus spp*. on the incidence of root-rot:*

Pepper transplants (30- day- old) sown in infested or uninfested soil with any of *G. etunicatum*, *G. mosseae*, *G. diaphanum*, *G. luteum* and *G. coronatum* in a nursery were transplanted in pots (25 cm in diam.), filled with sterilized soil, which was infested with sclerotia of any of the two isolates of *S. rolfsii* (40 sclerotia/pot). Inoculum-free pots were used as a control. Four replicates were used for each treatment and were sown in greenhouse with the following treatments:

1- Pepper plants sown in soil infested with *Glomus* spp.
2- Pepper plants individually infested with both *Glomus* spp. and *S. rolfsii*.
3- Pepper plants sown in soil infested with *S. rolfsii*.
4- Pepper plants sown in inoculum-free soil.

Growth parameters of pepper plants, *i.e.* plant height (cm), fresh weight of shoot-system and root –system (g), dry weight of shoot-system and root –system (g), No. of fruits and fruit weight (g) were recorded 90 days after planting. Disease severity of rotted roots caused by *S. rolfsii* was recorded 6 weeks after planting using the scale of Flores-Moctezuma *et al.* (2006) as follows:

0 = 100% plants without symptoms.
1 = yellowing.
2 = at least 50% of plants with wilt and death.
3 = more than 50% plants with wilt and death.

DSL = [disease level x No. of infection plants/total plants x 4] X 100.

Statistical analysis:

Data were statistically analyzed according to the standard procedure in completely random design or split-split plot as mentioned by Snedecor and Cochran (1982).

Results

Collection, isolation and purification of vesicular arbuscular mycorrhizal (VAM) fungi:

Data in Table (1) show the main morphological characteristics (colour, shape and size) to determine the differentiation among species of genus *Glomus*. The shape was not critical character where all species had globose and subglobose shape but some spores of *G. mosseae* and *G. coronatum* had irregular shape. Also, the identification was made according to the size of the spores. *G. mosseae* and *G. etunicatum* spores which were large (< 100 µm) but they were different in colour; (*G. mosseae* hyaline-dark orange to brown and *G. etunicatum* pale orange brown to dark orange brown).

Effect of Glomus spp. *on the rate of pepper seed germination:*

Data in Table (2) show that 4 species of *Glomus* spp., *i.e*. *G. etunicatum*, *G. diaphanum*, *G. luteum* and *G. coronatum* increased the percentages of survived pepper seedlings cv. Inhatem M (73.33, 80, 73.33 and 66.67%, respectively) compared with control treatment (60%). In the contrary *G. mosseae* gave insignificant result compared with control.

Table 1. Morphological characteristics of *Glomus* spp. isolated from three governorates in Egypt

Governorate	Species	Colour	Shape	Size
Beni Suef	*G. etunicatum*	Orange to red brown	Globose, subglobose	90-129µm
Ismailia	*G. mosseae*	Hyaline to dark orange-brown	Globose, subglobose, irregular	100-150µm
	G. diaphanum	Hyaline to white	Globose, subglobose	60-85µm
Menofiya	*G. luteum*	Pale yellow to dark yellow with a brownish tint	Globose, subglobose	50-84µm
	G. coronatum	Pale orange brown to dark orange brown	Globose to subglobose	80-140µm

Table 2. Effect of *Glomus* spp. on the rate of pepper seed germination

Tested isolate	Survived seedlings (%)
G. etunicatum	73.33*
G. mosseae	56.67
G. diaphanum	80.00
G. luteum	73.33
G. coronatum	66.67
Glomus-free treatment	60.00
L.S.D. at 0.05	5.00

* Mean of 30 replicates.

Effect of treatment with Glomus spp. *on disease severity of Sclerotium root-rot of pepper plants:*

Data in Table (3) show that pepper seedlings arose from seeds treated with *Glomus* spp. at nursery, reduced the percentages of disease severity of root-rot of pepper plants caused by *S. rolfsii* (4-11%) compared with that of either seedlings treated (4-15%) or untreated (30-41%) with *Glomus* spp. in the greenhouse Fig. (1).

The highest percentages of reduction in disease severity were recorded in treatments with *G. etunicatum* treated with *S. rolfsii* isolate I_1 (4%) and *G. diaphanum* treated with *S. rolfsii* I_1 and I_2 (4%) for both of seedlings arose from seeds treated with *Glomus* spp. On the other hand, the highest percentages of reduction in disease severity were recorded on seedlings treated with *G. etunicatum* (4.3-4.5%) treated with *S. rolfsii* I_1 and I_2, respectively, *G. diaphanum* (5.1%) treated with *S. rolfsii* I_1 and *G. luteum* (4%) and (5.6%) treated with *S. rolfsii* I_1 and I_2, respectively, as compared with seedlings untreated with *Glomus* spp.

Table 3. Effect of treatment with *Glomus* spp. on disease severity of Sclerotium root-rot of pepper plants

Treatment	*Glomus* spp. isolate	Disease severity of Sclerotium root-rot disease of pepper plants treated with *Glomus* spp.			
		I_1*	I_2	0**	Mean
Seedlings arose from seeds treated with *Glomus* spp.	*G. etunicatum*	4.0***	7.0	0.0	3.7
	G. mosseae	7.0	11.0	0.0	6.0
	G. diaphanum	4.0	4.0	0.0	2.7
	G. luteum	7.0	7.0	0.0	4.7
	G. coronatum	7.0	7.0	0.0	4.7
Seedlings untreated with *Glomus* spp.		30.0	41.0	0.0	23.7
Mean		9.8	12.8	0.0	-
Seedlings treated with *Glomus* spp.	*G. etunicatum*	4.3	4.5	0.0	2.9
	G. mosseae	9.0	15.0	0.0	8.0
	G. diaphanum	5.1	7.0	0.0	4.0
	G. luteum	4.0	5.6	0.0	3.2
	G. coronatum	7.0	11.0	0.0	6.0
Seedlings untreated with *Glomus* spp.		30.0	41.0	0.0	23.7
Mean		9.9	14.0	0.0	-
L.S.D at 0.05 for: Treatments (T) = 0.9; Glomus (G) = 1.2; Isolates (I) = 0.9; TxG = 2.1; TxI = 1.6; GxI = 2.1; TxGxI = 3.6					

* Isolates of *S. Rolfsii.*
** *S. rolfsii* free – treatments.
******* Each value represents the mean of 12 replicates.

Effect of Glomus spp. *on some crop parameters:*

Data in Tables (4-10) show that adding any of five *Glomus* spp., *i.e. G. etunicatum, G. mosseae, G. diaphanum, G. luteum* and *G. coronatum* to the soil increased the crop parameters, *i.e.* fresh and dry weight of pepper plants in all treatments, including plants sown in soil infested with *S. rolfsii* compared with plants sown in *Glomus*-free pots. On the other hand, the growth parameters of seedlings arose from seeds treated with *Glomus* spp. were higher than *Glomus*-free seedlings sown in soil mixed with *Glomus* spp. Fig. (2). All treatments of seedlings arose from seeds treated with *Glomus* spp. and Glomus-free seedlings sown in soil mixed with *Glomus* spp. were significantly increased plant growth (root and shoot) of pepper plants. Seedlings arose from seeds treated with *Glomus* spp., *G. etunicatum*, *G. luteum* and *G. coronatum* increased fruit production more than other species.

Table 4. Effect of *Glomus* spp. on plant height of pepper plants infected by *S. rolfsii*

Treatment	*Glomus* spp. isolate	Plant height (cm) of pepper plants infected with *S. rolfsii*			
		I_1*	I_2	0**	Mean
Seedlings arose from seeds treated with *Glomus* spp.	*G. etunicatum*	28.7***	28.7	30.1	29.2
	G. mosseae	25.1	24.6	28.6	26.1
	G. diaphanum	29.3	27.7	31.7	29.6
	G. luteum	26.3	26.6	33.5	28.8
	G. coronatum	29.7	24.1	32.9	28.9
Seedlings untreated with *Glomus* spp.		16.1	12.5	22.6	17.1
Mean		25.9	24.0	29.9	-
Seedlings treated with *Glomus* spp.	*G. etunicatum*	22.6	25.9	26.9	25.1
	G. mosseae	21.6	27.0	28.0	25.5
	G. diaphanum	22.6	24.0	24.6	23.7
	G. luteum	25.8	26.3	29.2	27.1
	G. coronatum	26.5	21.0	29.4	25.6
Seedlings untreated with *Glomus* spp.		16.1	12.5	22.6	17.1
Mean		22.5	22.8	26.8	-
L.S.D at 0.05 for: Treatments (T) = 1.0; Glomus (G) = 1.7; Isolates (I) = 0.3; TxG = 2.4; TxI = 1.8; GxI = 3.1; TxGxI = 4.4					

*; ** & *** As described in footnote of Table (3).

Table 5. Effect of *Glomus* spp. on shoot fresh weight of pepper plants infected by *S. rolfsii*

Treatment	*Glomus* spp. isolate	Shoot fresh weight (g)/ plant of pepper plants infected with *S. rolfsii*			
		I_1*	I_2	0**	Mean
Seedlings arose from seeds treated with *Glomus* spp.	*G. etunicatum*	6.3***	6.5	7.2	6.7
	G. mosseae	4.9	5.3	7.3	5.8
	G. diaphanum	7.9	7.5	9.6	8.3
	G. luteum	5.6	5.6	8.8	6.7
	G. coronatum	6.9	4.0	7.0	6.0
Seedlings untreated with *Glomus* spp.		1.5	1.1	2.7	1.8
Mean		5.5	5.0	7.1	-
Seedlings treated with *Glomus* spp.	*G. etunicatum*	4.0	3.9	4.1	4.0
	G. mosseae	2.2	3.9	4.8	3.9
	G. diaphanum	3.9	3.1	4.3	3.8
	G. luteum	3.6	4.3	5.4	4.4
	G. coronatum	4.1	3.6	4.7	4.1
Seedlings untreated with *Glomus* spp.		1.5	1.1	2.7	1.8
Mean		3.2	3.3	4.3	-
L.S.D at 0.05 for: Treatments (T) = 1.5; Glomus (G) = 1.8; Isolates (I) = 0.5; TxG = 1.1; TxI = 0.6; GxI = 1.1; TxGxI = 1.6					

*; ** & *** As described in footnote of Table (3).

Table 6. Effect of *Glomus* spp. on shoot dry weight of pepper plants infected by *S. rolfsii*

Treatment	*Glomus* spp. isolate	Shoot dry weight (g)/ plant of pepper plants infected with *S. rolfsii*			
		I_1*	I_2	0**	Mean
Seedlings arose from seeds treated with *Glomus* spp.	*G. etunicatum*	3.3***	3.1	3.7	3.4
	G. mosseae	2.8	2.7	3.2	2.9
	G. diaphanum	3.0	3.0	3.8	3.3
	G. luteum	3.3	2.9	4.0	3.4
	G. coronatum	3.0	2.2	3.9	3.0
Seedlings untreated with *Glomus* spp.		0.6	0.6	1.4	0.9
Mean		2.6	2.4	3.3	-
Seedlings treated with *Glomus* spp.	*G. etunicatum*	1.9	1.7	2.4	2.0
	G. mosseae	1.8	2.2	2.5	2.2
	G. diaphanum	1.1	1.4	1.6	1.4
	G. luteum	2.2	1.9	2.9	2.3
	G. coronatum	1.6	1.5	3.0	2.0
Seedlings untreated with *Glomus* spp.		0.6	0.6	1.4	0.9
Mean		1.5	1.6	2.3	-
L.S.D at 0.05 for: Treatments (T) = 0.2; Glomus (G) = 0.3; Isolates (I) = 0.3; TxG = 0.4; TxI = 0.4; GxI = 1.7; TxGxI = 1.0					

*; ** & *** As described in footnote of Table (3).

Table 7. Effect of *Glomus* spp. on root fresh weight of pepper plants infected by *S. rolfsii*

Treatment	*Glomus* spp. isolate	Root fresh weight (g)/ plant of pepper plants infected with *S. rolfsii*			
		I_1*	I2	0**	Mean
Seedlings arose from seeds treated with *Glomus* spp.	*G. etunicatum*	2.9***	3.4	4.9	3.7
	G. mosseae	3.6	2.3	5.0	3.6
	G. diaphanum	3.9	2.2	5.1	3.7
	G. luteum	2.5	2.3	6.5	3.8
	G. coronatum	2.9	2.6	6.0	3.8
Seedlings untreated with *Glomus* spp.		0.9	0.6	1.1	0.9
Mean		2.7	1.8	4.8	-
Seedlings treated with *Glomus* spp.	*G. etunicatum*	1.2	1.3	1.4	1.3
	G. mosseae	0.8	1.2	1.4	1.1
	G. diaphanum	0.8	1.3	1.1	1.2
	G. luteum	1.1	0.9	1.5	1.2
	G. coronatum	1.4	0.8	1.6	1.3
Seedlings untreated with *Glomus* spp.		0.9	0.6	1.1	0.9
Mean		1.0	1.0	1.4	-
L.S.D at 0.05 for: Treatments (T) = 0.2; Glomus (G) = 0.4; Isolates (I) = 0.2; TxG = 0.5; TxI = 0.3; GxI = 0.5; TxGxI = 0.7					

*; ** & *** As described in footnote of Table (3).

Table 8. Effect of *Glomus* spp. on root dry weight of pepper plants infected by *S. rolfsii*

Treatment	*Glomus* spp. isolate	Root dry weight (g)/ plant of pepper plants infected with *S. rolfsii*			
		I_1*	I_2	0**	Mean
Seedlings arose from seeds treated with *Glomus* spp.	*G. etunicatum*	1.9***	1.6	2.5	2.0
	G. mosseae	1.8	1.5	2.3	1.9
	G. diaphanum	1.9	1.8	2.1	1.9
	G. luteum	1.6	1.4	2.0	1.7
	G. coronatum	1.7	1.3	2.5	1.8
Seedlings untreated with *Glomus* spp.		0.5	0.3	0.6	0.4
Mean		1.6	1.3	2.0	-
Seedlings treated with *Glomus* spp.	*G. etunicatum*	0.9	0.8	1.2	1.0
	G. mosseae	0.7	1.0	1.3	1.0
	G. diaphanum	0.6	0.7	0.7	0.7
	G. luteum	0.8	0.9	1.3	1.0
	G. coronatum	0.9	0.8	1.2	0.9
Seedlings untreated with *Glomus* spp.		0.5	0.3	0.6	0.4
Mean		0.7	0.8	1.0	-
L.S.D at 0.05 for: Treatments (T) = 0.1; Glomus (G) = 0.2; Isolates (I) = 0.1; TxG = 0.3; TxI = 0.2; GxI = 0.3; TxGxI = 0.5					

*; ** & *** As described in footnote of Table (3).

Table 9. Effect of *Glomus* spp. on number of fruits of pepper plants infected by *S. rolfsii*

Treatment	*Glomus* spp. isolate	Numbers of fruit (g)/ plant of pepper plants infected with *S. rolfsii*			
		I_1**	I_2	0**	Mean
Seedlings arose from seeds treated with *Glomus* spp.	*G. etunicatum*	0.7***	1.0	1.3	1.0
	G. mosseae	1.0	0.0	0.7	0.6
	G. diaphanum	0.7	0.7	0.7	0.7
	G. luteum	0.7	0.7	0.7	0.7
	G. coronatum	1.0	0.3	2.7	1.3
Seedlings untreated with *Glomus* spp.		0.0	0.0	0.0	0.0
Mean		0.7	0.5	1.0	-
Seedlings treated with *Glomus* spp.	*G. etunicatum*	0.3	1.0	1.0	0.8
	G. mosseae	0.3	0.0	0.7	0.3
	G. diaphanum	0.7	0.7	0.3	1.0
	G. luteum	0.3	0.7	0.7	0.6
	G. coronatum	1.0	0.0	1.0	0.7
Seedlings untreated with *Glomus* spp.		0.0	0.0	0.0	0.0
Mean		0.4	0.4	0.6	-
L.S.D at 0.05 for: Treatments (T) = 0.2; Glomus (G) = 0.4; Isolates (I) = 0.2; TxG = 0.5; TxI = 0.4; GxI = 0.6; TxGxI = 0.9					

*; ** & *** As described in footnote of Table (3).

Table 10. Effect of *Glomus* spp. on fruit weight of pepper plants infected by *S. rolfsii*

Treatment	*Glomus* spp. isolate	Fruit weight (g)/ plant of pepper plants infected with *S. rolfsii*			
		I_1*	I_2	0**	Mean
Seedlings arose from seeds treated with *Glomus* spp.	*G. etunicatum*	2.4***	2.5	7.7	4.2
	G. mosseae	1.2	0.0	3.1	1.4
	G. diaphanum	2.8	2.0	3.9	2.9
	G. luteum	2.2	1.3	8.2	3.9
	G. coronatum	2.3	1.2	8.3	3.9
Seedlings untreated with *Glomus* spp.		0.0	0.0	0.0	0.0
Mean		1.8	1.2	5.2	-
Seedlings treated with *Glomus* spp.	*G. etunicatum*	1.9	3.7	2.6	2.1
	G. mosseae	1.2	0.0	2.0	1.1
	G. diaphanum	1.0	0.8	2.4	1.4
	G. luteum	1.3	2.2	2.1	1.9
	G. coronatum	2.2	0.0	3.7	2.0
Seedlings untreated with *Glomus* spp.		0.0	0.0	0.0	0.0
Mean		1.3	2.2	2.1	-
L.S.D at 0.05 for: Treatments (T) = 0.1; Glomus (G) = 0.2; Isolates (I) = 0.2; TxG = 0.3; TxI = 0.3; GxI = 0.5; TxGxI = 0.7					

*; ** & *** As described in footnote of Table (3).

Fig. 1. Seedlings arose from seed treated with *G. coronatum* (A) were higher than seedlings treated with *G. coronatum* (B) compared with control (C).

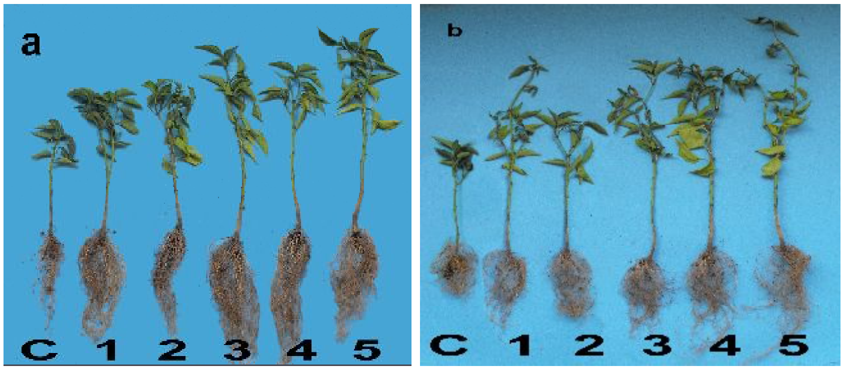

Fig. 2. Effect of *Glomus* spp. on root rot disease of pepper caused by *S. rolfsii* I_1 (a) Seedlings arose from seed treated with *Glomus* spp. and (b) Seedlings treated with *Glomus* spp. compared to control (C). *G. etunicatum*, *G. mosseae*, *G. diaphanum*, *G. luteum* and *G. coronatum*, respectively.

Discussion

Four species of genus *Glomus*, *i.e. G. etunicatum*, *G. diaphanum*, *G. luteum* and *G. coronatum* increased the percentages of survived pepper seedlings cv. Inhatem M (73.33, 80, 73.33 and 66.67%, respectively) compared with control treatment (60%). Inoculation during sowing the seeds then transplanting was the best effective method for promoting plant growth. Some cases which were inoculated during sowing showed better growth. It was possibly due to early inoculation of mycorrhiza spread rapidly to new roots during germination (Ikiz *et al*., 2009). Gomez *et al*. (1999) showed that the arbuscular mycorrhizal fungi (AMF) colonization essentially accompanied with plant growth increases. Vegetable crops that require a nursery stage can benefit from AMF inoculation, thus its use has been incorporated into horticultural practices (Evans, 1997).

In this study, *G. mosseae* gave non-significant result compared with that in control. Oseni *et al.* (2010) demonstrated that inoculating tomato seedlings did not promote significantly seedling growth, but positively affected growth and development resulting in higher biomass dry weight and root/shoot ratio with beneficial implications for tomato growth and yield. Giri *et al*. (2005) reported that under nursery conditions, mycorrhizal inoculation improved growth of seedlings. Root and shoot dry weights were higher in mycorrhizal than non-mycorrhizal plants. AM fungi significantly enhanced root and shoot dry weights of nursery-raised seedlings 30 and 60 days after planting. The effect of AM inoculation on plant growth varied with the fungal species used. Increased root and shoot dry weights in mycorrhiza-colonized plants may be the result of increased supply of nutrients (Requena *et al.,* 1997), water relations (Auge *et al*., 1995) and carbohydrate partitioning (Graham *et al.,* 1997) by mycorrhizal fungi.

All treatments of seedlings arose from seed treated with *Glomus* spp. and *Glomus*-free seedlings sown in soil mixed with *Glomus* spp. were significantly increased plant growth (root and shoot) and fruit production of pepper plants. Seedlings arose from seeds treated with *Glomus* spp., *G. etunicatum*, *G. luteum* and *G. coronatum* increased fruit production more than other species. Haas *et al*. (1987) reported that pepper yield increased with mycorrhizal inoculation compared with uninoculated ones. The researches in the last decades indicated that symbiosis of some kinds of mycorrhiza with plants root facilitates the absorption of nutrient elements such as P and Zn. The best known advantage of arbuscular mycorrhizal (AM) fungi inoculation is the increase of the plant growth and increase of fruit yield. This positive effect is especially due to enhancing uptake of nutrients. Sreenivasa *et al*. (1993) observed that inoculation of chili (*Capsicum annum* L.) with mycorrhizal fungi *G. fasciculatum* increased fruit yield, shoot, and phosphorus concentration compared with controls. Also they found that inoculation with *G. macrocarpum* had greater effect than inoculation with *G. fasciculatum*. Al-Raddad (1987) grew pepper inoculated plants with *G. fasciculatum*, *G. monosporum* and *G. mossea* under greenhouse conditions and found that the dry weight of the plants increased significantly. The mycorrhizal fungi can increase plant growth by enhancing uptake of nutrients (Ikiz *et al*., 2009). The obtained results revealed that colonization by AM fungus resulted in higher dry weights of biomass compared to the non-inoculated (control) treatments, suggesting that the AM fungus significantly contributed the pepper plant growth.

In recent years, mycorrhizal fungi as symbiotic organisms have been used against plant pathogens successfully. This study established that, mycorrhizal fungi reduced the severity of infection by *S. rolfsii* (I_1) and (I_2) of pepper plants by AMF varied between 4-15%. Liu (1995) investigated the effect of mycorrhizal fungi on Verticillium wilt of cotton and the role of disease resistance. However, disease severity was decreased by mycorrhizal fungal inoculation under suitable condition and wilt severity was lower compared to control. Ozgonen *et al*. (2010) investigated the effect of AMF against stem rot disease caused by *S. rolfsii* Sacc. in peanut. The mycorrhizal fungi used were *G. etunicatum, G. mosseae, G. calarum, G. caledonium, G. fasculatum* and *Gigaspora margarita*. In pot experiments, mycorrhizal fungi decreased infected plant by 17.5-84%. *G. caledonium* showed the highest effect, it was 84%. Several studies indicated that AMF influenced fungal diseases caused by root pathogens (Matsubara *et al*., 1995; Trotta *et al*., 1996 and Karagiannidis *et al*., 2002). Most of the studies concluded that, disease severity could be reduced by root colonization with AMF via several mechanisms including the increase of mineral absorption and plant growth (Davies and Linderman, 1991 and Smith and Read, 1997), pathogenesis – related proteins (Pozo *et al*., 1999) and phenolic compounds (Devi and Reddy, 2002). The improvement of growth parameters and dry weight by *Glomus* spp. is not new and it is documented for different crops (Aguilera-Gomez *et al*., 1999). But the fungus (*Glomus* spp.) also significantly improved the growth parameters of Sclerotium- infected plants. These results are in agreements with those obtained by (Ozgonen *et al*., 2010).

The benefits of *Glomus* sp. in improving pepper growth and reducing *S. rolfsii* damage were more pronounced when seedlings arose from seed treated with *Glomus* spp. Azcon-Aguilar and Barea (1997) showed that mycorrhizal association can modify the duration of life cycle of *Capsicum annum* L. Plants colonized by *G. mosseae* exhibited shorter vegetative period than non-mycorrhizal plants and plants associated with *G. deserticola* or *G. intraradices*. However, the earlier beginning of reproductive stage in pepper colonized by *G. mosseae* was not avoiding yield reduction when plants were inoculated with *V. dahliae*. On the other hand, the effectiveness of AMF as biocontrol agents varied among different *Glomus* species, which agreed with findings of Habte *et al.* (1999). In pepper colonized by *G. intraradices*, the severity of the disease was even higher than that observed in nonmycorrhizal plants in terms of plant growth and pepper yield. The possible influence of endogenous phenolics in roots on the tolerance or resistance of pepper against wilt induced by *V. dahliae* remains unclear. However, we found that the highest reduction in growth and yield corresponded to plants that showed the lowest content of phenolic compounds in roots 43 days after the inoculation with the pathogen-those colonized by *G. intraradices*. In addition, high effectiveness in improving plant nutrition and growth was not necessary related to great effectiveness in protecting pepper against *Verticillium* induced wilt. Only plants associated with *G. deserticola* exhibited greater yield than non-mycorrhizal ones despite the lower P fertilization applied to the mycorrhizal treatment (Garmendia *et al.*, 2004).

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(Received 15/01/2013;
in revised form 19/02/2013)

دور فطريات الميكوريزا الداخلية فى مكافحة مرض عفن الساق والجذور فى الفلفل المتسبب عن الفطر *Sclerotium rolfsii*

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أُجريت هذه الدراسة لمعرفة مدى تأثير توقيت التلقيح بفطريات الميكوريزا الحويصلية الشجيرية *Glomus* على التفاعل بين عفن الجذور وعفن الساق لنباتات الفلفل المتسبب عن الفطر *Sclerotium rolfsii* وقد أشارت النتائج إلى أن إضافة الفطر *Glomus* spp. قد زادت معنوياً من الوزن الرطب والجاف للساق والجذر فى حين أنها خفضت معنوياً فى مستوى شدة المرض (٥٩ - ٨٩%). تم بحث تأثير التلقيح بفطريات الميكوريزا باستخدام ٥ أنواع من الجنس جلومس عن طريق معاملة اللقاح بطريقتين مختلفتين على النمو الخضرى لنباتات الفلفل وحمايتها ضد عفن الساق الأسكليروشيومى. بصفة عامة التلقيح بفطريات الميكوريزا زادت من الوزن الجاف والرطب للمجموع الخضرى والجذرى لنباتات الفلفل مقارنة بالنباتات غير الملقحة بالميكوريزا. في حين أن الشتلات التى نشأت من بذور معاملة بالميكوريزا زادت من مؤشرات النمو والمحصول. الأنواع *G. coronatum* و *G. Luteum* كانت أفضل الأنواع المُستخدمة لزيادة النمو فى حين أن الأنواع *G. etunicatum* ! *G. Diaphanum* و *G. luteum* كانت أفضلهم فى حماية نباتات الفلفل من الإصابة بالفطر *S. rolfsii* .