

## Applications of Vesicular Arbuscular Mycorrhizal Fungi for Sustainable Agriculture in Jordan

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Received on 1/7/2021 and Accepted for Publication on 29/8/2021.

### ABSTRACT

The beneficial vesicular-arbuscular mycorrhizal fungi are found in the rhizosphere of many plants. These fungi are promising for sustainable agriculture especially in poor soils and under stress conditions. Many genera were naturally found in Jordan soils, especially *Glomus*, and were significantly effective in improving plant growth of several vegetable crops whether they were growing under mineral deficiency or drought conditions. Also, many soil-borne fungi as *Fusarium*, *Verticillium*, and *Rhizoctonia* as well as root-knot nematodes were successfully controlled under Jordan's conditions. This type of biological control has a lower cost impact, safe and environment friendly.

**Keywords:** *Glomus*, *Fusarium*, *Verticillium*, *Rhizoctonia*, *Meloidogyne*, Plant Growth.

### INTRODUCTION

Intensive research developments in the study of mycorrhizas in Jordan have encouraged us to present a review article on the progress in this field. Most plant species can benefit from symbiotic associations with various types of mycorrhizal fungi (Al-Momany, 1983; Al-Momany, 1987; Saleh and Al-Momany, 1987). Vesicular-arbuscular (VA) mycorrhizae, which are common in legumes (Asai, 1944), can increase phosphorus uptake of plants growing in infertile or low phosphate soil (Powell and Daniel, 1978) mainly because of the capacity of mycorrhizal fungi to absorb phosphate from soil and transfer it to the host root (Gianinazzi-Pearson and Gianinazzi, 1980). There has recently been increased interest in the possible use of *Rhizobium* and VA mycorrhizal fungi together as a means of improving legume production. Recent investigations on the *Rhizobium*-mycorrhizal fungi-legume association have shown that modulation is better, and that nitrogen fixation,

dry weights, and phosphorus contents were higher when plants were infected with VA mycorrhizal fungi (Daft and EI-Giahmi, 1976; Smith and Daft, 1977). An increase in nodule biomass for plants inoculated with both rhizobia and mycorrhizal fungi was concluded to be the major factor increasing N<sub>2</sub> fixation rates (Kucey and Paul, 1982). The purpose of this paper was to clarify the beneficial effect of different VA mycorrhizal fungi on crop plants growing under stress conditions.

VA fungi used were collected from different crops in Jordan and classified according to Trappe (1982). Control plants received filtered washings from near roots to supply the same microflora without *Glomus* spp. A basal fertilizer mixture containing all nutrients was given fortnightly to all pots at a rate of 50 ml per pot from 0.05% fertilizer solution (Nitrofoska: 10% N, 4% P, 7% K). The amount of mycorrhizal colonization was assessed microscopically after clearing and staining 1-cm root segments. (Phillips and

Hayman, 1970). Fifty root segments were examined per plant and mycorrhization was expressed as either incidence (percentage of colonized segments) or intensity. All results were assessed using analysis of variance; mean separation was by Duncan's multiple range test at the 5% level.

#### Endomycorrhizal Fungi in Jordan:

Endomycorrhizal fungi are cosmopolitan biotrophic microorganisms that form a symbiotic relationship with many plants. This type of association seems to be necessary for plant existence because the symbiont provides the plant with many things other than minerals. The maximum benefit appears when the plant is growing under stress conditions. The best symbionts are the endophytic isolates which are adapted for the local environmental conditions. So, we started looking for local isolates in since 1984. The incidence of endomycorrhizal fungi and the occurrence of endogenous spores were investigated in roots and rhizospheres of different crops grown in different rain-fed areas in Jordan. 81% of soil and root samples analyzed possessed vesicular-arbuscular mycorrhiza. Endophytes belonged to the *Glomus* species. Six species were isolated from soil samples including *Glomus fasciculatum*, *G. mosseae*, *G. etunicatum*, *G. Melanosporum*, *G. pallidum*, and *G. monosporum* (Al-Momany 1993). *Glomus fasciculatum* was found to be associated with 33% of soil samples (Table 1). The incidence of root colonization ranged from 3 to 92%. Different crops exhibited different *Glomus* species and different stages of fungal invasion ranging from hyphae, arbuscules, and vesicles or combinations of all structures. Generally, one *Glomus* species was isolated from the rhizosphere of each sample and only 9% of the samples contained more than one type of endogenous spores. Only 17% of olive and grape samples were mycorrhizal-free. *Glomus fasciculatum* and *G. etunicatum* were the most dominant species found in soils planted with cereals and legumes. The maximum number of *Glomus* spores was isolated from an apricot rhizosphere while the lowest was from the rhizosphere of an apple tree. Highly significant correlation coefficients were found between spore count and

soil phosphorus content for the following crops: grape, barley, lentil, wheat, olive, apple, and chickpea.

**Table 1: Occurrence of *Glomus* species in 180 sites tested in rainfed areas in Jordan.**

Glomus	% of sites that contain the fungus	Symbol
<i>G. etunicatum</i>	15	E
<i>G. fasciculatum</i>	33	F
<i>G. melanosporum</i>	11	M
<i>G. monosporum</i>	2	N
<i>G. mosseae</i>	19	S
<i>G. pallidum</i>	7	P

The occurrence of mycorrhizal fungi on crops under irrigation was higher than in rain-fed areas where mycorrhizal spores were found in all 100 soil samples collected from Jordan Valley (Al-Momany 1989). Spore number differed from site to site and ranged from 18-418 spores /100-gram dry soil and varied considerably for the same crop at different sites. In general, there were more spores in soils planted to vegetables than in the case of those planted to fruit trees. Of the nine species found, *G. pallidum*, *G. mosseae*, and *G. fasciculatum* were the commonest. Few spores of *G. Etunicatum* and *G. monosporum* were also frequent but *Gigaspora* sp. was rare (Table 2). Nine mycorrhizal species were reported under high pH values for the first time in Jordan.

**Table 2: Occurrence of Endogonaceae species at the 100 sites tested in Jordan Valley.**

Glomus	% of sites that contain the fungus	Symbol
<i>G. Caledonium</i>	6	C
<i>G. etunicatum</i>	21	E
<i>G. fasciculatum</i>	40	F
<i>G. melanosporum</i>	4	M
<i>G. monosporum</i>	9	N
<i>G. mosseae</i>	60	S
<i>G. pallidum</i>	83	P
<i>Gigaspora</i>	1	G
<i>Acaulospora laevis</i>	5	A

**Mass Production of *Glomus mosseae* Spores:**

Vesicular-arbuscular (VA) endophytes are obligate biotrophic fungi forming symbiotic relationships with the roots of many plants (Van-Geel, *et al*, 2016; Al-Momany, 1987). The broad use of VA mycorrhizal (VAM) fungi has been limited because none of the VAM fungi have been cultivated in vitro and it is, therefore, difficult to obtain large quantities of prime inoculum. Many VAM fungi produce asexual chlamydospores or azygospores, which are thought to be of primary importance in the life cycles of the fungi, although root- and soil-borne vesicles, as well as mycelium also contributes to their reproductive potential.

Our studies have provided information on the effect of host plants on the spore production of a VAM fungus and the relationship of spore production to root colonization and plant age. Five crops inoculated with *Glomus mosseae* were grown for 10 weeks and the development of mycorrhizal structures and sporulation were assessed. The effectiveness of each host was assessed by measuring spore numbers. For all hosts, the percentage of root length colonized increased rapidly up to 10 weeks after sowing. Colonization of roots increased with an increasing percentage of root length colonized with the inoculum for all crops, except where large numbers of mature spores (1755) had been produced? on

barley (Al-Momany, 1995). The highest spore numbers were achieved in the rhizosphere of barley plants, followed by chickpea and beans. The lowest spore numbers were found in the rhizosphere of corn and okra plants. The type of the crop, as well as the harvest date greatly influenced the size of the spore population and the extent of root colonization of *G. mosseae*.

**Effect of Mycorrhizae on Plant Growth:****Response of Bean, Broad bean and Chickpea****Plants to Inoculation with *Glomus* Species**

All mycorrhizal plants showed higher shoot weights than the control plants (Table 3). *Glomus fasciculatum* 2 and *G. mosseae* 2 were the most effective isolates in maximizing the shoot growth of bean and chickpea plants (Al-Momany, 1991). In broad beans, *G. pallidum* 1 also improved shoot growth considerably. In general, the shoot growth of beans was not affected, only *G. pallidum* gave a significant increase. However, the root growth of broad beans was significantly improved by all isolates. Root growth of chickpea was variable. Concerning all isolates, chickpea and broad bean plants responded to *Glomus* inoculation much better than beans.

**Table 3: Effect of vesicular-arbuscular mycorrhizal fungi on the shoot, and root fresh weight of bean, broad bean, and chickpea plants (g per plant).**

Glomus spp.		Bean		Broadbean		Chickpea	
		Shoot	Root	Shoot	Root	Shoot	Root
<i>G. mosseae</i>	1	28.6 bcd	6.8 b	24.0 b	14.3 cd	7.9 cd	3.3 c
<i>G. fasciculatum</i>	1	27.0 bcd	6.9 b	24.5 b	12.7 d	7.0 d	5.7 b
<i>G. etunicatum</i>		30.7 b	7.4 b	19.0 c	13.7 cd	11.7 b	3.6 c
<i>G. monosporum</i>		29.6 bc	8.0 b	24.7 b	11.9 d	11.1 b	2.7 c
<i>G. pallidum</i>	1	25.2 d	8.0 b	30.5 a	19.2 a	8.9 c	7.3 a
<i>G. fasciculatum</i>	2	35.1 a	8.2 b	28.4 a	18.0 ab	13.5 a	4.9 b
<i>G. pallidum</i>	2	28.6 bc	9.7 a	24.0 b	16.5 ab	8.5 c	3.6c
<i>G. mosseae</i>	2	35.4 a	8.1 b	28.6 a	18.1 ab	14.8 a	5.4 b
Control		23.3 d	6.6 b	13.2 d	8.8 e	5.1 e	2.6 c

Within columns, values with at least one superscript in common are not significantly different at the 5% level.

### **Fruit and Rhizobium Nodules.**

At the end of the experiment, significant differences in fruit weight were demonstrated for the various isolates (Al-Momany, 1991). The most effective isolates were *G. mosseae* 2 and *G. mosseae* 1. Inoculation treatments with broad beans resulted in considerable increases in nodule weights in comparison with naturally occurring *Rhizobium* nodules in the control plants. *Glomus mosseae* 1 and *G. mosseae* 2 were the most effective isolates in colonizing the roots of bean, broad bean, and chickpea plants.

### **Response of Okra to Vesicular Arbuscular Mycorrhizal Isolates:**

It is very important to determine the most effective host-fungus combination for practical use in the field. Mycorrhizal okra plants grew better than the control treatment with higher plants increasing up to 72 % in 40 days after planting (Saleh and Al-Momany, 1987). Total plant weight and shoot dry weight of *Glomus etunicatum* inoculated plants were 436 % and 611 % greater than the non-mycorrhizal plants.

### **Use of Heat-Treated Olive Cake as Organic Fertilizer for Tomato Plants.**

The dry olive cake obtained from an olive fruit mill in Jordan was heat-treated at 494°C or 230°C for 3 and 6 hrs. before being used as organic fertilizer for tomato plants. The arbuscular mycorrhizal fungus *Glomus intraradices* (isolate H510) was inoculated to one-half of the plants. Plants were fertilized with Hewitt-solution without phosphorus (Al-Momany & Al-Saket 1989). Shoot fresh weight of mycorrhizal tomato plants given olive cake treated at 494 °C for 6 h was improved by 760 % and by 410 % respectively in plants given the same substrate but heated for 3 hrs. compared with mycorrhizal control plants growing in pure sand. While shoot fresh weight of non-mycorrhizal tomato was improved by 917% and by 744% respectively (Al-Momany, 2019). There was no growth response if the olive cake was heated only to 230°C before use. A negative relationship was found between temperature and duration of

olive cake treatment and mycorrhizal colonization. Olive cake samples heated at 494 °C for 6 and 3 h contained higher amounts of all minerals than samples treated at lower temperatures. High mineral supply from the heat-treated olive cake at 494 °C effectively stimulated plant growth. This fertilizer is safe and easy to handle due to its non-bulky weight.

### **Effect of Different Endomycorrhizal Fungi on Onion Growth**

Vesicular arbuscular mycorrhizae (VAM) are a symbiotic association between a fungus and the root system of vascular plants belonging to Phylum Glomeromycota (Gosling, *et al.*, 2006; Goussous, & Mohammad 2009). They were first described a century ago, since then much has been learned about their structure, distribution, physiology, and ecology (Harley and Smith, 1983). Mycorrhizal fungi are the most widespread fungal symbionts that colonize the root system of over 90% of plant species to the mutual benefit of both host and fungus (Garmendia, 2004). The external mycelium acts as a bridge that transfers water and minerals from the soil to roots (Yadav, *et al.*, 2012). Fossil evidence and DNA sequence analysis (Simon, *et al.*, 1993) suggested that this mutualism appeared 400- 460 million years ago when the first plants were colonizing land (Wang and Qiu 2006). VAM-fungi is associated with improved growth of many plant species due to increased nutrient uptake, production of growth-promoting substances, tolerance to drought, salinity, transplant shock, and synergistic interaction with other beneficial microorganisms such as nitrogen fixers and phosphorus solubilizers (Al-Momany, 1990). Hyphae of VAM explore a larger volume of soil and phosphate solubilization from unavailable sources present in the soil (Goussous and Mohammad 2009). VAM-fungi are unique and important components of the soil biota, and their occurrence, activity, and efficiency can be valuable indicators of soil quality and agricultural sustainability (Nakatani, *et al.*, 2011).

The mycorrhizal fungus used in all products was *Glomus intraradices* (Schenck, & Smith, 1982). Effect of four Mycorrhizal products on onion growth treated with; half dose, recommended dose, and, the double dose was summarized in Table 4. There were no significant differences between mycorrhizal plants and control plants in all parameters in the half dose and recommended dose treatments (Al-Hmoud & Al-Momany, 2020). However, in double dose treatments, leaf number, bulb weight, and, dry

shoot weight (DSW) in mycorrhizal plants were significantly different than control plants. Height of onion plants was enhanced by inoculation with Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof by 16, 28, 26, and 28%, respectively. Fresh root weight was increased significantly by mycorrhizal products; Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof by 260, 496, 386, and 502%, respectively.

**Table 4. Effect of three doses of four commercial mycorrhizal products on onion growth.**

Treatment	Dose (g/L soil)	Height (cm)	Bulb wt.	DSW (g)	FRW (g)
Bacto_Prof	0.5	38.9 cd	1.73 bc	0.57 cde	1.29 d
	1	42.0 abcd	1.74 bc	0.68 bcd	2.16 d
	2	43.42 abc	2.51ab	0.73 abcd	3.89 c
Endomyk_Basic	4	38.58 cd	1.12 c	0.39 e	1.312 d
	8	41.44 bcd	1.41 bc	0.70 abcd	1.76 d
	16	47.66 a	3.25 a	0.94 ab	6.43 a
Endomyk_Conc	0.5	40.08 cd	1.45 bc	0.58 cde	1.38 d
	1	40.9 cd	1.72 bc	0.67 bcde	2.01 d
	2	47.04 ab	3.70 a	0.83 abc	5.25 b
Endomyk_Prof	1	40 cd	1.17 c	0.54 de	1.28 d
	2	41.06 bcd	1.29 bc	0.58 cde	1.83 d
	4	47.9 a	3.54 a	0.98 a	6.5 a
Control	0	37.3 d	1.27 bc	0.57 cde	1.08 d

Values are average of five plants, values within each column followed by the same letter are not significantly different ( $P < 0.05$ ) according to LSD

#### **Effect of Different Commercial Mycorrhizal Products on Squash Growth**

Effect of four mycorrhizal products on squash growth treated with three doses; half dose, recommended dose, and the double dose was summarized in Table 5. In half dose treatments, there were significant differences in plant height, FSW, and FRW. Plant height was improved significantly by

all mycorrhizal products over the control plants; Bacto\_Prof, Endomyk\_Conc and Endomyk\_Prof by 11% and Endomyk\_Basic by 14% (Al-Hmoud & Al-Momany, 2017). Squash FRW was enhanced significantly in Endomyk\_Basic and Endomyk\_Conc by 25 and 24% above control plants, respectively. Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof by 17, 18, 19, and 13%

in comparison to control plants, respectively. FRW were increased by Bacto\_Prof, Endomyk\_Basic, and Endomyk\_Conc products significantly more than control plants; by 43, 58, and 61%, respectively. In double dose treatments, there were significant differences in plant height,

FSW, DSW, and FRW. Plant height was increased by all mycorrhizal products more than control plants; Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof by 40, 46, 44, and 40%, respectively.

**Table 5: Effect of three doses of four mycorrhizal products on squash growth compared with control.**

Treatment	Dose (g/L soil)	Height (cm)	DSW (g)	FRW (g)
<b>Bacto_Prof</b>	0.5	29.9 d	2.2 b	4.6 cde
	1	31.7 cd	2.5 b	4.8 bcd
	2	33.7 abc	3 a	5.3 abcd
<b>Endomyk_Basic</b>	4	30.9 d	2.4 b	4.9 bcd
	8	32 cd	2.4 b	5.4 abcd
	16	35.3 a	3.4 a	6 a
<b>Endomyk_Conc</b>	0.5	29.9 d	2.4 b	4.9 bcd
	1	32.2 bcd	2.6 b	5.5 abc
	2	34.7 ab	3 a	5.6 ab
<b>Endomyk_Prof</b>	1	30 d	2. b	4.5 de
	2	30.6 d	2.4 b	4.7 cde
	4	33.8 abc	3 a	5.5 abc
<b>Control</b>	0	24.1 e	2.2 b	3.4 e

Values are average of five plants, values within each column followed by the same letter are not significantly different ( $P < 0.05$ ) according to LSD.

#### **Effect of Endomycorrhizal Fungi on Tomato Growth:**

The effect of three different locally obtained *Glomus* spp. including *Glomus fasciculatum*, *Glomus monosporum*, and *Glomus mosseae* were tested in the field by inoculating tomato, eggplant, and pepper seedlings. As parameters for measuring the effect of endomycorrhizal fungi on plant growth, plant height, shoot fresh weight, total yield, fruit size, and length of leaf blade was used. The shoot fresh weight of eggplant was increased up to 47%, 28%, 29% by inoculating with *Glomus mosseae*, *Glomus monosporum*, and *Glomus fasciculatum*, while total yield per plant was increased up to 60%, 43%, and 7%, respectively (Al-Momany, 1987).

In half dose, tomato FRW was enhanced significantly by Endomyk\_Basic product by 55%. For the recommended dose, the height was increased significantly only in the

Bacto\_Prof product by 26% more than the control treatment. For FRW, the variation was increased significantly by all products; Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof by 66, 70, 58, and 58% in comparison to the control, respectively. In double dose-treated plants, the height of all products was increased significantly by 36, 39, 26, and 29% in Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof, respectively (Al-Hmoud, 2012). FRW was improved more than control by 104, 103, 80, and 78%, respectively in Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof. The double dose was highly efficient than the recommended dose and half-dose referring to plant height, FSW, and FRW. The total yield of the tomato plants was increased up to 47%, 23%, and 9% by inoculating with *Glomus mosseae*, *Glomus monosporum*, and *Glomus fasciculatum* while the shoot

fresh weight was increased up to 59%, 48%, and 9% respectively (Al-Momany, 1987).

### Effect of Endomycorrhizal Fungi on Pepper

#### Growth:

The total yield of the pepper plant was increased up to 22%, 21%, and, 7% by inoculating with the three *Glomus* species respectively. The most effective fungus was *Glomus mosseae* which improved plant growth of the three inoculated crops but *Glomus fasciculatum* was the most efficient isolate in colonizing roots of eggplant and peppers (Al-Momany, 1987). The effect of commercial mycorrhizal products on pepper growth planted with three doses was presented in Table 6. In half dose treatment, the height of pepper crop was enhanced significantly by Endomyk\_Basic product only by 10% compared with control treatment (Al-Hmoud, 2012). In the recommended dose, plant height was enhanced significantly only by Endomyk\_Basic and Endomyk\_Prof by 18 and 9% more than control plants,

respectively. Plant FRW was improved significantly by all products; Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof by 76, 57, 50, and 50%, respectively.

In double dose treatment, there were no significant differences between mycorrhizal treated plants and control plants in fruit weight. Plant height was enhanced significantly by all mycorrhizal products; Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof by 30, 34, 32, and 24%, respectively in comparison with untreated plants. Plant DSW was increased by all products; Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof by 60, 59, 65, and 45%, respectively compared with control plants. FRW was enhanced significantly by all products; Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof by 58, 68, 64, and 53%, respectively over the control plants. By comparing the three doses together, there were no significant differences in flower number, fruit number, fruit weight, and FRW; but in plant height and DSW double dose was highly efficient than the recommended dose and half dose.

**Table 6. Effect of three doses of different mycorrhizal commercial products on pepper growth compared with control.**

Treatment	Dose (g/L soil)	Height (cm)	DSW (g)	FRW (g)
Bacto_Prof	0.5	34.1 f	0.93 ef	5.03 c
	1	35.5 def	1.07 cdef	5.83 abc
	2	43.7 ab	1.37 ab	6.33 ab
Endomyk_Basic	4	37.2 c	1.14abcde	5.46 bc
	8	39.7 d	1.31 abc	6.29 ab
	16	45.1 a	1.36 ab	6.73 a
Endomyk_Conc	0.5	34.7 ef	1.00 def	5.44 bc
	1	35.8 def	1.11 bcdef	5.97 abc
	2	44.4 a	1.42 a	6.56 a
Endomyk_Prof	1	34.6 ef	1.07 cdef	5.12 c
	2	36.6 de	1.26 abcd	6.00 abc
	4	41.5 bc	1.24 abcd	6.13 ab
Control	0	33.6 f	0.85 f	4.00 d

Values are average of five plants, values within each column followed by the same letter are not significantly different ( $P < 0.05$ ) according to LSD

### Effect of Endomycorrhizal Fungi on Bean

#### Growth:

Effect of the four commercial mycorrhizal products on bean growth treated with three doses; half dose, recommended dose, and the double dose was presented in Table 7. In the half dose treatment, plant height was not

significantly different in Bacto\_Prof and Endomyk\_Prof, while significant in Endomyk\_Basic and Endomyk\_Conc (Al-Hmoud, 2012). Plant FRW was significantly increased with mycorrhizal products compared with non-mycorrhizal plants; by 36, 53, 38, and 36% for Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof

products, respectively. For the recommended dose, plant height was increased significantly more than control plants; Bacto\_Prof by 9%, Endomyk\_Basic by 12%, Endomyk\_Conc, and Endomyk\_Prof by 11%. (Table 7).

In double dose treatment, plant height was highly significant in all mycorrhizal products; Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof by 13, 16, 14, and, 13%, respectively more than control plants.

Plant DSW was improved with three mycorrhizal products compared with non-treated plants by 31, 24, and 22% for Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof products, respectively. However, plant FRW was highly significant in all mycorrhizal products; and improved by Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof by 51, 77, 68, and 61%, respectively compared with control plants.

**Table 7. Effect of three doses of different mycorrhizal commercial products on bean growth compared with control.**

Treatment	Dose (g/Lsoil)	Height(cm)	Fruit wt. (g)	DSW(g)	FRW(g)
Bacto_Prof	0.5	24.9 de	2.10 bc	2.29 cd	4.60 e
	1	26.4 bcd	2.57 abc	2.42 bcd	4.79 ed
	2	27.3 abc	1.85 c	2.51 bcd	5.11 dce
Endomyk_Basic	4	26.2 bcd	3.11 a	2.50 bcd	5.20 bcd
	8	27.1abc	3.32 a	2.63 abc	5.08 dce
	16	28.1 a	3.09 a	2.87 a	5.99 a
Endomyk_Conc	0.5	25.8 cd	3.39 a	2.49 bcd	4.67 de
	1	26.9 abc	3.27 a	2.59 abc	5.06 dce
	2	27.4 ab	2.71 abc	2.71 ab	5.69 ab
Endomyk_Prof	1	25.2 de	3.03 ab	2.46 bcd	4.66 de
	2	26.9 abc	3.02 ab	2.53 abcd	4.96 dce
	4	27.4 ab	2.82 abc	2.68 ab	5.46 abc
Control	0	24.1 e	3.00 ab	2.19 d	3.39 f

Values are average of five plants, values within each column followed by the same letter are not significantly different ( $P < 0.05$ ) according to LSD.

#### Use of Mycorrhizal Fungi and as Biocontrol

##### Agents Against Root Pathogens:

##### Effect of Mycorrhizal Fungi in Combination with Soil Solarization to Control Panama Disease of Banana in Jordan Valley.

Soil solarization was applied to a field that was planted with infected banana seedlings. Banana cv. Grand Naine plantlets were chemically treated as soil drench with Nanoparticle solution of 200 and 400 ppm of Silver Nanoparticles (AgNPs), two fungicides, Revanol and Tachigaren, Sodium Hypochlorite in addition to irrigation of one treatment with treated wastewater. Biological control included three treatments: Endomycorrhiza, Trichoderma as a commercial product (BioHealth), and plant growth-promoting rhizobacteria (Al-Momany *et. al.*, 2019; Shen, *et*

*al.*, 2018). Fresh chicken and sheep manure were added to two treatments. Endomycorrhizal inoculation with *Glomus mosseae*, 200 ppm of AgNPs, Revanol, and Tachigaren treatments of banana seedlings was the most effective in completely protecting banana plants from *Fusarium* wilt during the whole experimental period (Table 8). Several applications of *Trichoderma*, wastewater, and 400 ppm of AgNPs were effective in maintaining some infected banana seedlings nine months after planting very healthy. Sheep and chicken manure treatments resulted in 60 and 40% disease incidence with *Fusarium* wilt respectively and 20% of disease incidence in Hypex, PGPR, and control treatments. Wastewater, Nanoparticles 200 ppm, and endomycorrhizal treatments gave the highest ratio of sword sucker development.



**Table 8. Disease incidence of banana treated with different treatments at different dates.**

Treatment	% of infected plants at different dates (Disease incidence)				
	16-01-2018	08-02-2018	15-03-2018	15-05-2018	12-07-2018
<b>Endomycorrhiza Glomus spp.</b>	0	0	0	0	0
<b>Trichoderma spp.</b>	0	40	0	0	0
<b>Wastewater</b>	0	20	20	0	0
<b>Hypex</b>	0	20	0	20	20
<b>AgNPs 200ppm</b>	0	0	0	0	0
<b>AgNPs 400ppm</b>	0	0	20	0	0
<b>Sheep manure</b>	0	40	0	40	60
<b>Chicken manure</b>	0	0	0	40	40
<b>Revanol</b>	0	0	0	0	0
<b>Tachigaren</b>	0	0	0	0	0
<b>PGPR</b>	0	20	0	20	20
<b>Control</b>	0	0	0	20	20

**Interactive Effect of *Glomus mosseae* and *Paecilomyces lilacinus* on *Meloidogyne javanica* of Tomato.**

Root-knot nematodes are important plant pathogens affecting crop production throughout the world. In Jordan, *Meloidogyne* spp. is considered a big problem for plants, especially tomatoes, in irrigated areas (Abu Gharbieh 1988). Recent problems caused by the intensive use of nematicides have enhanced the development of biocontrol methods for integrated management of plant-parasitic nematodes with antagonistic organisms (Cabanillas and Barker 1989). Predacious and parasitic fungi constitute the largest and most promising group of nematode antagonists (Qadri, 1989). Parasitic fungi found to be successful bioagents against nematodes include *Paecilomyces lilacinus*, *Fusarium oxysporum*, and *F. solani* (Abu-Laban, 1991). Recent experiments have shown that infection of tomato, white clover, lucerne, and grape by VAM fungi decrease the incidence of disease, limits nematode development and activity in plant roots, and minimizes growth suppression by root-knot nematodes (Cooper and Grandison 1986). The effects of *Glomus mosseae* and *Paecilomyces lilacinus* on *Meloidogyne javanica* of tomato were tested in a greenhouse experiment. Inoculation of tomato plants with *G. mosseae* did not markedly increase the growth of infected plants with *M. javanica* (Table 9). Inoculation of plants with *G. mosseae* and *P. lilacinus* together or separately resulted in similar shoots and plant heights. The highest root development was achieved when mycorrhizal plants were inoculated with *P. lilacinus* to control root-knot nematode (Al-Momany, 1995). Inoculation of tomato plants with *G. mosseae* suppressed gall index and the average number of galls per root system by 52% and 66%, respectively (Table 9), compared with seedlings inoculated with *M. javanica* alone. Biological control with both *G. mosseae* and *P. lilacinus* together or separately in the presence of layer manure completely inhibited root infection with *M. javanica*. Mycorrhizal colonization was not affected by the layer manure treatment or by root inoculation with *P. lilacinus*. The addition of layer manure had a beneficial effect on plant growth and reduced *M. javanica* infection.

**Table 9: Effect of *G. mosseae* and *P. lilacinus* on *M. javanica* infection and mycorrhizal colonization of tomato plants. Within columns values with at least one letter in common are not significantly different at the 5% level.**

Treatment		Gall index Scale 1-5	Average number of galls per root system	Mycorrhizal colonization	
Fungi	<i>M. javanica</i>			Incidence %	Intensity %
Control	-----	0	0	0	0
<i>G. mosseae</i>	+	1.2	22	23	3
No fungi	+	2.5	65	0	0
Layer manure	+	0.6	10	0	0
<i>P. lilacinus</i>	+	0	0	0	0
<i>G. mosseae</i> + Layer manure	+	0	0	24	5
<i>G. mosseae</i> + <i>P.</i> <i>lilacinus</i>	+	0	0	30	5

#### Use of Endomycorrhizal fungi to control Verticillium Wilt of Cucumber.

*Verticillium dahliae* is a soil-borne fungus that causes Verticillium wilt of cucumber and many other crops (Zhang *et al.*, 2018; Sowik, *et al.*, 2016; Roustae & Baghdadi, 2007). The effectiveness of *Glomus mosseae* and *Glomus fasciculatum* to control Verticillium wilt on cucumber was assessed under greenhouse conditions (Tahat and Al-Momany, 2021). The height of cucumber plants inoculated with *G. fasciculatum* was significantly (138.5cm) different compared to all other treatments, but the combined treatments (*G. mosseae* & Verticillium, *G. fasciculatum* & Verticillium) were similar to control plants 117.5cm, 122.5cm, 121cm respectively (Tahat and Al-Momany, 2019). Leaves number were in *G. mosseae* treatment not significantly different compared with the combined inoculation of *G. mosseae* and Verticillium. Cucumber shoot and root biomass were significantly increased in *G. fasciculatum* treatments compared with *G. fasciculatum* & *V. dahliae* treatment. Disease severity was decreased significantly in the combined treatments of *G. mosseae* and Verticillium, *G. fasciculatum*, and Verticillium (2.5, 3.2 respectively) as compared to *V. dahliae* infected plants (Table 10).

**Table 10. Disease severity of cucumber inoculated or not with *V. dahliae* and/or *G. fasciculatum* and *G. mosseae***

Treatment	Disease severity/ Weeks		
	Week 8	Week 9	Week 10
VD	6.0a	6.0 a	6.5 a
GM +VD	2.7 b	2.7 b	2.5b
GF + VD	2.5 b	3.0 b	3.2 b

Means followed by the same letter within columns are not significantly different as determined by Tukey Post Hoc Test ( $P=0.05$ ). Whereas *Glomus mosseae* (GM), *Glomus fasciculatum* (GF), *Verticillium dahliae* (VD).

Roots colonized by both species of mycorrhizal fungi were higher compared to combined treatments of the AMF and Verticillium. Mycorrhizal spore production was higher in plants inoculated with *G. mosseae* compared with the other treatments. *G. fasciculatum* & *V. Dahliae* and *G. mosseae* & *V. dahliae* treated plants were more significantly tolerant to disease infection compared with Verticillium infected plants.

Plants inoculated with *G. fasciculatum* were significantly the highest compared to other treatments at the end of the 8th, 9th, and 10th week from planting. Plant height of *Verticillium* treated plants was the shortest at the end of the 10th week of plant age and was significantly different compared with other treatments. (Orak, *et al.*, 2011; Tahat and Al-Momany, 2019). At the end of the experiment, both treated plants with AMF + *V. Dahliae* were statistically different. Also, both *Glomus* species' treatments were significantly different from each other.

#### Root and Shoot Biomass.

Both mycorrhizal species were able to increase the root and shoot dry and fresh matter significantly in the single treatment of *G. mosseae* as well as *G. fasciculatum*. *Verticillium*-infected treatment showed the lowest root and shoot weight compared with all other plants (Tahat and Al-Momany, 2019). On the other hand, the pathogen treatment showed the lowest dry root weight.

#### Use of *Glomus mosseae* and Olive Cake to Control *Rhizoctonia solani* of Pepper.

Chili pepper can be attacked by different soil-borne fungi that mainly cause root rot and damping-off such as *Rhizoctonia solani*, *Pythium* spp., and *Fusarium* spp. These pathogens favor poorly drained soils. *Rhizoctonia* damping-off in chili pepper is becoming a threatening disease in Jordan. AMF was collected and extracted from different soil locations in Jordan, identified, and manipulated on wheat as plant stock culture for three months (Tahat, *et al.* 2020). The results showed that single inoculation with *Glomus mosseae* and double inoculation by *G. mosseae* + *R. solani* treatments had the highest values in all growth parameters with no significant differences (Table 11). The disease severity was 70% for *R. solani* treated seedlings compared to the *G. mosseae* + *R. solani* treated plants (30%), whereas the disease severity of *G. mosseae* + OC seedlings was 50% (Tahat, *et al.* 2020). In conclusion, *G. mosseae* was a very good biological practice in controlling chili pepper damping-

off disease when used alone but mixing *G. mosseae* with OC decreased the efficacy of *G. mosseae*.

**Table 11: Effect of different treatments on diseases severity of chili pepper roots infected with *Rhizoctonia solani***

Treatments	Disease severity (%)
<b><i>Rhizoctonia solani</i></b>	70
<b><i>Glomus mosseae</i>, + <i>Rhizoctonia solani</i></b>	30
<b>olive cake + <i>Rhizoctonia solani</i></b>	50
<b><i>Glomus mosseae</i> + olive cake + <i>Rhizoctonia solani</i></b>	40
<b>Control</b>	0

#### Use of *Glomus* Commercial Products to Control *Fusarium* Root Rot.

Mycorrhizal fungi are the most widespread fungal symbionts that colonize the root system of over 90% of plant species to the mutual benefit of both the plant host and fungus (Smith & Read 1997; Garmendia *et al.*, 2004) either extracellularly as in ectomycorrhizal fungi or intercellularly as in arbuscular mycorrhizal (AM) fungi. Vesicular arbuscular mycorrhiza (VAM) colonizes plant roots and extends into the surrounding bulk soil to the root depletion zone around the root system (Bethlenfalvay & Barea 1994). The major role of VA-fungi is to supply plant roots with phosphorus because phosphorus is an extremely immobile element in soils (Wetterauer & Killorn, 1996). Two main groups of soil-borne pathogens have been studied: nematodes and fungi such as *Phytophthora* spp., *Verticillium* wilt, and *Fusarium* wilt. In the presence of AM fungi, a reduction in the pathogen population or the disease severity on the host plant has been demonstrated. Also, AMF protects the unsupervised root from parasitic fungi by increasing wall thickness in the cortical cells of the roots (Al Ameiri 1987).

#### Effect of VA Mycorrhizal Fungi on *Fusarium* Infected Tomato Plants.

The effect of *Fusarium oxysporum* on tomato growth was presented in Table 12. Considering plant height,

Bacto\_Prof was highly significant than all other products by 44%, and all mycorrhizal products were significantly higher than control plants by 29, 31, and 26% in Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof, respectively (Al-Momany, 1988; Al-Momany, *et al.*, 2014; Al-Hmoud & Al-Momany 2015). However, the increase in plant FRW was enhanced more in mycorrhizal plants than in non-

mycorrhizal plants by 154% for Bacto\_Prof and Endomyk\_Basic, while in Endomyk\_Conc and Endomyk\_Prof the increase was 134%. Infection percentage in non-mycorrhizal plants was the highest by 8% compared with the mycorrhizal plants by 4% for Bacto\_Prof, Endomyk\_Conc, and Endomyk\_Prof and 5% for Endomyk\_Basic product.

**Table 12: Effect of Fusarium oxysporum with the recommended dose of mycorrhizal products on growth of tomato plants.**

Treatment	F. oxysporum	Height (cm)	DSW (g)	FRW (g)	Severity (cm)	Infection %
<b>Bacto_Prof</b>	+	51.6 a	1.868 ab	4.904 a	2.1a	4%
	-	50.2 ab	1.734 ab	4.678 a	0b	0
<b>Endomyk_Basic</b>	+	46.4 abc	1.844 ab	4.898 a	2.3a	5%
	-	45.4 bc	2.006 a	4.798 a	0b	0
<b>Endomyk_Conc</b>	+	47.1 abc	1.842 ab	4.5 a	1.8a	4%
	-	42.5 cd	1.648 ab	4.614 a	0b	0
<b>Endomyk_Prof</b>	+	45.2 bc	1.656 ab	4.568 a	2a	4%
	-	42 cd	1.636 ab	4.438 a	0b	0
<b>Control</b>	+	35.9 e	1.146 c	1.932 b	2.8a	8%
	-	39.8 ed	1.35 bc	2.808 b	0b	0

Values are average of five plants, values within each column followed by the same letter are not significantly different ( $P < 0.05$ ) according to LSD. (+) means inoculated with *F. oxysporum* while (-) means non-inoculated with *F. oxysporum*.

#### **Effect of VA Mycorrhizal Fungi on Fusarium Infected Pepper Plants.**

There were significant differences in plant height in Fusarium treatments between mycorrhizal plants and non-mycorrhizal plants. Plant height of mycorrhizal plants infected with Fusarium was improved by 20, 27, 21, and 25% by Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof products, respectively (Al-Momany, 1988; Al-Hmoud & Al-Momany 2015). Plant DSW was enhanced significantly by all mycorrhizal products; Bacto\_Prof, Endomyk\_Conc, and Endomyk\_Prof by 56, 102. 85 and 98%, respectively compared to control plants. infected with Fusarium. Plant Fusarium infection percentage in pepper control plants was the highest 2.45%, compared to 1.32 and 1.5% in Endomyk\_Conc and Endomyk\_Basic treatments, respectively.

#### **Effect of VA Mycorrhizal Fungi on Fusarium Infected Eggplant.**

The four products were not significantly different from each other, and all were significantly different from control plants infected with Fusarium. Plant height in Fusarium treatment with mycorrhizal products was enhanced by 14% for Bacto\_Prof, 16% for Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof (Al-Hmoud & Al-Momany 2015). Plant FSW in Fusarium treatment was raised 49% by Bacto\_Prof and 51% by Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof over non-mycorrhizal plants. Infection percentage in control plants was the highest (5.80%) compared with 3.50, 2.22, 3.42, and 2.72% for Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof, respectively.

### Effect of VA Mycorrhizal Fungi on Fusarium Infected Squash Plants.

Plant height in Fusarium treatment with Endomyk\_Basic was 24% higher than control plants inoculated with Fusarium, followed by 8, 7, and 6%, respectively for Endomyk\_Prof, Endomyk\_Conc, and Bacto\_Prof (Al-Hmoud & Al-Momany 2015). Squash FRW in Fusarium treatment was enhanced by 69, 88, 73, and 67% for Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof, respectively compared to control plants infected with Fusarium. Infection percentage in non-mycorrhizal squash plants was the highest by 14.45% compared with 9.41, 10.13, 10.92, and 11.69% for Bacto\_Prof, Endomyk\_Basic, Endomyk\_Conc, and Endomyk\_Prof products, respectively.

### Use of Endomycorrhizal Fungi to Control Verticillium Wilt of Olive.

Many reports indicated an interaction between VA mycorrhizal fungi and plant pathogenic organisms (Al-

Momany, 1988 and 1995). Wilt of tomato caused by *Fusarium oxysporum* f.sp. *lycopersici* was reduced when plants were pre-inoculated with *Glomus mosseae*. In general, mycorrhizal plants suffer less damage and the incidence of the disease is decreased, or the pathogen development is inhibited (Dehne, 1982; Abu-Qamar and AL-Momany 2002; Karagiannidis, *et al.*, 2002; Bubici and Cirulli, 2012; Sowik, *et. al.*, 2016). Shoot dry weights of olive seedlings inoculated with *Glomus mosseae* alone were significantly greater than those of plants inoculated with both *Verticillium dahlia* and *G. mosseae* (Karajeh and Al-momany, 1999). Table (13) indicated that disease severity was higher for plants inoculated with *V. dahlia* alone than plants inoculated with *Glomus mosseae* and *V. dahlia* and it was 36.2% in non-mycorrhizal roots compared to 14.3% in mycorrhizal roots.

**Tab 13: Effect of *G. mosseae* on the growth of olive seedlings and disease severity of *Verticillium* wilt of olive.**

Treatment	Shoot dry weight g/plant	Rate of increase in plant height %	Disease severity %	Mycorrhizal colonization %
<b>Verticillium</b>	44.2	171	36.2	0
<b>G. mosseae</b>	62.2	224	0	26.3
<b>Verticillium + G. mosseae</b>	53.8	187	14.3	23.8
<b>Control</b>	45.9	169	0	0

### Effect of Mycorrhizal Fungi on Plant Drought Tolerance:

In many semiarid regions of the world, drought and infertile soils with low phosphorus concentrations combine to limit crop productivity. In these regions, most wheat (*Triticum durum*) is grown under rainfed conditions, where drought can occur at any time during the growing season. It has been demonstrated, in the absence of indigenous arbuscular mycorrhizal (AM) fungi, that plant nutrition and growth can be improved by inoculating the soil with these symbiotic microorganisms (Ellis *et al.* 1985; Kupulnik and

Kushnir 1991). The mycorrhizal enhancement of P, Zn, Cu, Mn, and Fe uptake, and the growth of plants subjected to low soil P and adequate water supply is well documented (Nelsen 1987; Michelsen and Rosendahl 1990; Raju *et al.* 1990a; Manjunath and Habte 1991). Mycorrhizal associations with plant roots not only enhance growth and mineral element uptake but may also confer greater resistance to drought (Hardie and Leyton 1981; Davies *et al.* 1992; Ruiz-Lozano *et al.* 1995). It has been suggested that mycorrhizal colonization is a host-dependent and heritable trait (Lackie

*et al.* 1988; Mercy *et al.* 1990; Zou, *et al.*, 2013). To determine whether mycorrhizal infection influences host plant responses to drought stress, growth parameters under well-watered and water-stressed conditions were monitored in wheat genotypes with distinct differences in drought resistance.

Mycorrhizal colonization of both wheat genotypes was reduced by drought stress (Al-Karaki and Al-Momany, 1997). Under well-watered but not water-stressed conditions, the roots of the drought-resistant genotype

CR057 showed a significantly higher AM colonization than the roots of the drought-sensitive genotype CR006 (Table 14). Total and root dry matter yields increased after inoculation of soil with *G. mosseae*. The phosphorus status of leaves stems, and flower heads showed that P uptake was stimulated by AM inoculation in both genotypes, independent of water availability. (Table 14).

**Table 14 Calculated mycorrhizal (AM) increases in total dry matter yield and total nutrient uptake of AM wheat grown under water-stressed and non-stressed conditions.**

Treatment	Genotype	Total dry matter <sup>a</sup>	P <sup>b</sup>	Zn	Mn	Cu	Fe
Nonstressed	CR057	42	68	18	51	50	56
	CR006	38	79	47	41	64	34
Stressed	CR057	35	53	17	40	61	43
	CR006	45	87	46	53	68	60

a Total dry matter (DM) increase=(DMAM-DMnonAM) x100/DMnonAM

b Nutrient uptake (NU) increase=(NUAM-NUnonAM) x100/NUnonAM

Drought stress reduced the P content of leaves, stems, and flower heads in both mycorrhizal and non-mycorrhizal plants. A significant drought stress X AM interaction was noted for P content in leaves, stems, and whole plants but not in flower heads. Genotypic differences in P content due to AM inoculation were noted in stems and flower heads only under well-watered conditions. CR006 had more P than CR057 in stems, while CR057 had more P than CR006 in flower heads. Leaf, stem, and flower head Zn content declined under drought-stress conditions regardless of AM inoculation in both genotypes. AM inoculation significantly increased the Zn content of leaves and stems but not flower heads. A significant difference between genotypes for Zn content was noted only in flower heads, where CR057 accumulated more Zn than CR006 under well-watered conditions. Mn and Cu contents of leaves, stems, and flower heads were higher in mycorrhizal than nonmycorrhizal plants. Iron content was not affected by drought stress in

leaves or flower heads but was higher in stems in well-watered conditions. AM inoculation increased the Fe content of leaves and stems but did not affect the Fe content of flower heads. CR057 plants accumulated more Fe than CR006 in flower heads under well-watered conditions.

#### **Water Stress and Mycorrhizal Isolate Effects on Growth and Nutrient Acquisition of Wheat**

Arbuscular mycorrhizal (AM) colonized plants often have greater tolerance to drought than nonmycorrhizal (nonAM) plants. Mycorrhizal colonization was higher in well-watered (nonWS) plants colonized with both AM isolates than WS plants, and Gms had greater colonization than Gmn under both soil moisture conditions (Al-Karaki and Al-Momany 1996; Al-Karaki, *et al.*, 1998). Shoot and root DM were higher in AM than in nonAM plants irrespective of soil moisture, and Gms plants had higher shoot but not root DM than Gmn plants grown under either soil moisture condition. The AM plants had higher shoot Zn, Cu, and Fe concentrations and contents than nonAM plants.

The Gms plants grown under nonWS generally had higher nutrient contents than Gmn plants, but nutrient contents were similar for both Gms and Gmn plants grown under WS. The results demonstrated a positive relationship between enhanced growth and AM root colonization for plants grown under nonWS and WS.

#### **Effect of Soil Solarization on Endomycorrhizal Fungi**

Polyethylene plastic tarps of different colors were used to solarize the soil in a plastic house at the University Farm in the Jordan Valley during the Summertime. The soil of the plastic house was inoculated with four isolates of *Glomus mosseae* Gerd. and Trappe in the previous year by introducing pre-inoculated tomato seedlings (Al-Momany *et al.*, 1988; Stapleton, 1985; Karajeh and Al-Momany 2008).

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## استخدام فطريات "الاندومايكورايزا" للزراعة المستدامة في الأردن

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تاريخ استلام البحث: 2021/7/1 وتاريخ قبوله: 2021/8/29.

### الملخص

تتواجد فطريات الاندومايكورايزا النافعة في محيط المجموع الجذري لعدد كبير من النباتات. وتعد هذه الفطريات واعدة للزراعة المستدامة ولاسيما في التربة الفقيرة وتحت ظروف الكرب. ويوجد طبيعياً عدد كبير من أجناس هذه الفطريات في تربة الأردن وأهمها فطر *Glomus* ، وكانت فعالة بشكل كبير في زيادة نمو النبات والإنتاج لعدد من المحاصيل الخضرية سواء كانت مزروعة في التربة في المعادن الفقيرة أو تحت الظروف الجافة. كذلك تم مكافحة عدد من الفطريات المستوطنة في التربة مثل: فطر الفيوزاريوم، الفيرتيسليوم، والرايزوكتونيا ونيماتودا المعقدة للجذور بشكل فعال تحت ظروف الزراعة الأردنية، ويعد هذا النوع من مكافحة البيولوجية من الأنواع الاقتصادية الآمنة والصديقة للبيئة.

**الكلمات الدالة:** *Meloidogyne*, *Rhizoctonia*, *Verticillium*, *Fusarium*, *Glomus* , نمو النبات.